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OBSERVATIONS AND EXPERIMENTS ON DRAGON-FLIES IN BRACKISH WATER

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WHEN we consider the great variety and extent of adaptation among the insects, and especially when we recall the multitude of aquatic and semi-aquatic species, it seems rather remarkable that none of them has been able to take up marine life. Halobates, one of the Hemiptera, is truly oceanic, a few species of Diptera are known to live in sea water during their larval stage, a few larval forms have been found below high tide where they would be exposed to the sea water for a portion of the time, and a number of adult insects, chiefly beetles, range the shore finding their food when the tide is out.

In brackish water, however, many species are regularly found, belonging to nearly all the insect orders. It is a noteworthy fact that nearly all of these are more commonly found breeding in fresh water and are not peculiar to brackish water conditions.

While the occurrence of dragonfly nymphs in brackish ponds must have been noticed many times by observing naturalists, references in literature are exceedingly scant. Mr. E. A. Schwartz ("Preliminary Remarks on the Insect Fauna of the Gt. Salt Lake, Utah," *Can. Ent.*, vol. 23), found nymphs living in a mixture of salt and sulphurous or fresh water about Gt. Salt Lake, but adds: "The same species were also seen at Utah Lake, which is fresh water"; and the eminent authority on the dragonflies, Dr. P. P. Calvert in his "Catalogue of the Odonata of the Vicinity of Philadelphia" (*Trans. Amer. Ent. Soc.*, vol. 20, 1893) makes the

following statement: "No Odonate nymphs are known to live in salt water, but probably some coast species, such as *Ischnura ramburii* and *Micrathyria berenice* live in that which is brackish."

The writer's attention was first attracted to the presence of dragonflies in brackish water by the discovery that many common Pacific Coast species were breeding abundantly in a slightly brackish pond near Victoria, British Columbia. No estimate of the salinity could be made but it was slight. Again at Wood's Hole, Mass., many common forms were also found living in brackish ponds of varying density. The following list of species noted breeding in brackish water will serve to show what a variety of those ordinarily breeding in fresh water may, if occasion require, live equally well to all appearances in slightly salt water. At Victoria, B. C.: *Enallagma carunculatum, Ischnura pervarva, I. cervula, Aeschna californica, Sympetrum madidum, Mesothemis simplicicollis* var. *collocata, Libellula quadrimaculata,* and *L. forensis.* At Wood's Hole, Mass.: *Lestes unguiculatus, L. rectangularis, Nehalennia irene, Enallagma civile, Ischnura verticalis, Anax junius, Leucorhinia intacta, Micrathyria berenice, Sympetrum rubicundulum, Libellula pulchella, L. auripennis,* and *Plathemis lydia.* These records were obtained partly by identification of the nymphs, partly by rearing the imagos, and partly by collecting the young imagos just after their transformation. The Wood's Hole list represents only seven weeks collecting in July and August and in a very restricted locality so it is highly probable that the list represents only a few of those that may be found in brackish water. Of the above species, only one, *Micrathyria berenice,* is limited in its range to near the coast, and as it also breeds in fresh water in the same region it can hardly be said to be a typical brackish water species.

In order to determine the salinity of water in which dragonflies may live the following experiments and tests were made at Wood's Hole during the summer of 1905. As the work had to be pursued for the most part at odd moments my observations are not as complete as could be wished, and yet they are full enough to be quite significant. My thanks are due the U. S. Bureau of Fisheries for the opportunity to carry on the work while connected with the Wood's Hole Station as temporary scientific assistant.

In the first place, a series of salinometer tests of the water in all the ponds in which dragonfly nymphs were found, was made. Water from four such ponds on Nonnamesset Island and from three on the mainland was tested and in none of them was the density greater than 1.0015, while the average was about 1.0008. These tests were made at a temperature of 72° Fahr. and as the figures have not been reduced the actual density would be considerably greater. It will be noted, however, that water of such density contains but little salt in comparison with that of sea water, which has an average density of 1.026. One pond examined had a density of 1.015 at 72°, but, though dragonflies of several species were seen about this pond, a careful examination revealed no dragonfly nymphs living in the water and it is a safe assumption that the adults came from less saline ponds in the vicinity. Even if oviposition should take place under such conditions it is highly probable, as will be shown by the experiments to be discussed, that no eggs would develop.

Next, the experiment of placing nymphs in saline solutions of various densities was tried. Chiefly the nymphs of *Lestes unguiculatus*, an Agrionid, were used. These were taken from a pond of the density of 1.0012. Those placed in water which was entirely fresh showed no ill effects from the change, and the same is true of those put into saline solutions of low density, up to about 1.003. Beyond this point the larvæ showed increasing signs of irritation. In solutions at 1.005, 1.0075, and 1.01 the nymphs at first wriggled and swam violently, tried to climb up the sides of the aquaria and otherwise gave evidence of much irritation, but they apparently became inured to it after a day or so and lived as well in these solutions as in that in which they were found. Higher solutions were always fatal. In sea water at 1.02 they lived only a few hours, and at 1.015 they showed every sign of discomfort and invariably died within a day or so.

The larvæ of *Ischnura verticalis*, also an Agrionid, of *Anax junius*, an Aeschnid, and of several Libellulids, chiefly *Sympetrum rubicundulum*, showed entirely similar results.

Further experiments on the development of the eggs in brackish water yielded some interesting results tallying well with those made on the nymphs. Eggs of *Libellula auripennis* Burmeister

were taken just prior to oviposition on July 16, 1905. These were placed in solutions of various densities at 75° F. as indicated in the following table with the results noted:—

Density of water	Result
Fresh	hatched July 30
1.001	" " "
1.002	" " "
1.003	" " "
1.004	" " "
1.005	" " "
1.0075	" " "
1.010	" " "
1.015	Failed to hatch, partial development
1.020	" " " no development (?)

A glance at the above table shows that the amount of salinity from fresh water up to 1.010 had no effect whatever on the time of hatching; all hatched out together 14 days after fertilization. The 1.015 and 1.020 cultures were kept under exactly the same conditions but neither developed to the point of hatching. In the former considerable development took place, to the extent that the main structures of the larva were outlined, but in the latter no indications of development could be observed except some cases of questionable segmentation.
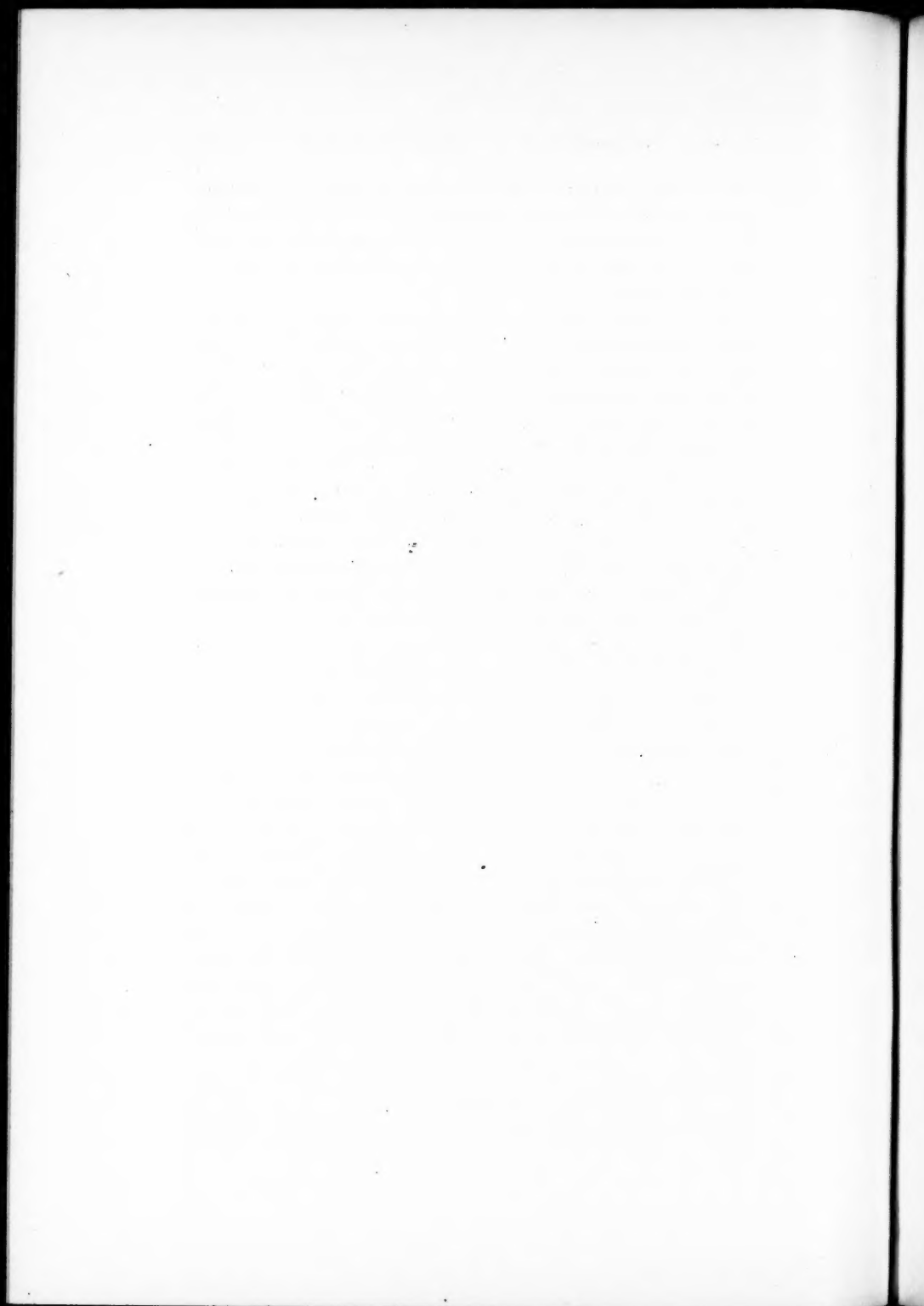
No differences could be noted between the larvæ hatched in 1.010 and those hatched in weaker solutions or fresh water and later experiments proved them to be equally hardy.

The young larvæ were now transferred to solutions differing from those in which they had been hatched, in order to test their resistance to density changes at this period. The results tally remarkably with those on the older nymphs and with the hatching experiments. Larvæ hatched in 1.010, 1.0075, and 1.005 solutions when placed in fresh water showed no discomfort and lived as well as those hatched in the fresh water, while those hatched in fresh water stood the change into the above solutions without any noticeable effect. The attempt to run any of them into higher solutions, however, always resulted fatally in a short time. In 1.015 they died in less than a day, in the 1.020 they were killed in

a few hours.   Those hatched in the 1.010 solution had apparently gained no further power of resistance but succumbed as quickly as those from fresh water.   This test was repeated after two weeks but with the same result, they still were overcome as readily as when first hatched.

The above experiments indicate that there is in the Odonata a very definite barrier to their assumption of marine life, and that this barrier remains unchanged during the life of the individual. That it is the same for all species has not yet been determined, and it may be that forms such as *Micrathyria berenice* which are limited in distribution to the coastline have a higher limit than those species which occur in the interior only.   As to the nature of the barrier we are entirely in the dark.   It may be that the eggs and nymphs of Odonata are able to prevent the osmosis of salt in solution up to a certain point, but it seems more probable that the metabolism is interfered with only by salt in solution above a certain density.   Whether other groups of insects are similarly restricted is also unknown.

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REACTIONS OF *TUBULARIA CROCEA* (AG.)
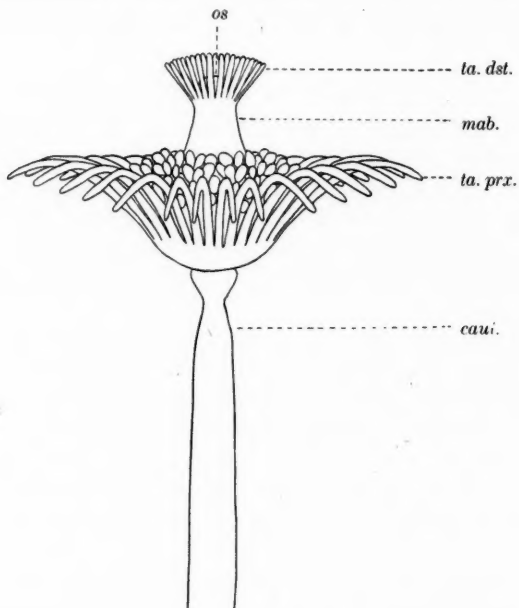
A. S. PEARSE

WHILE the reactions of sea anemones and of jelly fishes have been carefully studied, comparatively little is known of those of hydroids. In fact, the only recent paper which deals primarily with this subject is one by Torrey (:04) on *Corymorpha palma.* He found that this hydroid gives well marked reactions to gravity and mechanical stimulation, but does not respond to chemical stimulation.

The work upon which the present paper is based was undertaken at the suggestion of Professor G. H. Parker, and the experiments were carried on at the Laboratory of the United States Bureau of Fisheries at Wood's Hole, Mass. My thanks are due to the director, Dr. F. B. Sumner, for the courtesies shown me at the Wood's Hole Laboratory and to the Museum of Comparative Zoölogy for pecuniary assistance granted from the Humboldt Fund.

The material, consisting of colonies of Tubularia, was scraped from the piles of the wharf at the Fisheries Station and examined in sea water within three hours of the time of collection. The colonies are rather delicate and are easily rendered inactive or killed by unfavorable conditions. Small portions of colonies, containing from twenty-five to fifty polyps, were used in these experiments.

The accompanying figure represents an expanded hydranth of *Tubularia crocea* and a short portion of the stalk upon which it is borne. In a resting hydranth the proximal tentacles (*ta. prx.*) are bent slightly back toward the stalk (*caul.*) and remain motionless except for an occasional sudden movement toward the mouth (*os*), after which they slowly return to their former position. The distal tentacles (*ta. dst.*) are more active and are usually in motion,

401

bending back and forth singly or collectively. The manubrium
(*mab.*) is ordinarily motionless, but may shorten or lengthen and,
when stimulated, is capable of bending even to such an extent that

the mouth is brought below the bases of the proximal tentacles.
The whole hydranth may be moved by the bending of the stalk,
but this action is not of frequent occurrence and it is apparently
not called forth in response to direct stimulation.

MECHANICAL STIMULATION

When a proximal tentacle is touched with a needle or pinched,
it bends toward the manubrium. The strength of the stimulus
influences the response. If the stimulus is weak, there may be no
reaction, but if it is strong, the whole circle of tentacles may close
up together and press against the manubrium. If the manubrium
or the distal tentacles are stimulated in a similar manner, the for-

mer bends toward the point of stimulation and a few or all of the
distal tentacles wave about for a short time.   If in this process
they touch some object, they then close up around the mouth.
When the stimulation is very strong, the manubrium shortens and
both sets of tentacles close up around it.

The hydranths will submit to considerable mechanical stimu-
lation without reaction.   For example, a stream of water forced
from a pipette upon an expanded individual will cause no move-
ment unless the current is rather strong.

If a proximal tentacle is pulled vigorously, the manubrium will
turn so that the mouth is brought toward the stimulated point and
the distal tentacles will open out.   However, as each set of ten-
tacles may be made to react independently and without apparent
influence on the other set, it seems probable that in this case the
manubrium is strained and thus stimulated directly.

The reactions described above are doubtless helpful to the animal
in securing food, though they are not perfectly adapted to this pur-
pose.   They are not very accurately adjusted to the gathering of
food, for the proximal tentacles will always move toward the mouth
even when the point of stimulation is on the outer face, in which
case they move directly away from what may be food.

Chemical Stimulation

When a proximal tentacle is touched with a piece of meat at any
point, it bends toward the mouth.   The meat, if it is on the inner
face of the tentacle, is pressed against the mouth for a time and
then the tentacle slowly returns to its former place.   All the proxi-
mal tentacles often close up in the presence of meat, but those in
contact with it react first and remain closed after the others have
opened out, which they usually do quickly.   If meat is placed very
gently on the proximal tentacles, no reaction takes place and it falls
off or remains resting upon them.   Sometimes when meat is placed
upon them, the bending reaction takes place, but this is so feeble
that the meat does not move far enough to reach the distal tentacles
and in such cases there is no movement of the manubrium or distal
tentacles.   When meat comes in contact with the distal tentacles,

however, they bend outward and the manubrium turns them to-
ward the stimulated side. If they then touch the meat, they close
up around the mouth.

These reactions make it appear as though the procuring of food
depended wholly upon mechanical stimulation, as Torrey has
claimed in the case of Corymorpha; but the following experiments
have led to a somewhat different conclusion. When a grain of
sand is placed on one side of a hydranth,— being allowed to rest
upon the proximal tentacles and to touch the distal ones,— and a
piece of meat is placed in a corresponding position on the opposite
side, the manubrium almost invariably turns toward the meat and
the distal tentacles open out. In another experiment meat juice
was extracted and filtered. This filtrate has a milky appearance
and can easily be seen in water. When it is allowed to flow gently
from the mouth of a pipette on the proximal tentacles, no reaction
takes place, but as soon as it touches the distal tentacles they ex-
pand and the manubrium bends toward the stimulated side. To
prove that these reactions are not due to mechanical stimulation
produced by particles of solid matter or by currents, the same ex-
periment was tried using powdered carmine in sea water instead of
meat juice.

In 15% of the trials (685) with carmine water the mouth was
turned toward the stimulated side and the distal tentacles opened
out, but when the meat filtrate was used upon the same individuals
the turning and opening-out reactions took place in 82% of the
trials (717).

A third experiment points in the same direction. If the distal
tentacles of an active hydranth are touched several times with a
needle, they close tightly over the mouth. If, after a moment,
they are touched again with the needle, they remain closed for
some time; but if as a second stimulation they are touched in the
same manner with a piece of meat instead of a needle, they at once
open out and wave about.

From the above experiments it is reasonable to conclude that
the distal tentacles, and perhaps the manubrium, are sensitive to
a substance or substances contained in meat juice, while the
proximal tentacles are not.

The effect of other chemical substances was tested without ob-

taining particularly significant results.   When treated with dilute onion juice, quinine solution, or acetic acid, the hydranths closed up for a time, and if the solution was strong enough, they were killed.   These substances, unlike meat, produce the same reactions as does strong mechanical stimulation.

Filter paper soaked in meat juice, onion juice, clove oil, or oil of bergamot and held near the hydranth caused no reaction of any part, the animal being apparently insensitive to the resulting very dilute solutions.

Thermal Stimulation

Colonies of Tubularia were placed in glass dishes and the effect of a rise or fall in temperature noted.   When the temperature of the water was raised above 25° C. most of the animals were inactive, though two individuals turned the proboscis and opened out the distal tentacles when, at 27.5° C., they were touched with meat. No animal, after having been heated to 26° C. and then cooled again to normal[1] temperature, survived and reacted normally.   When the water was cooled to about 10° C. most individuals became inactive to meat, though a few reacted to this form of stimulation even at 0° C.   Probably the colonies survive any temperature down to near freezing, as individuals which had been for half an hour in water which was frozen (−2.2° C.) at the bottom of the dish and had a temperature of 1.5° C. at the top, gave the usual reactions thirteen hours later at a normal temperature.   In no case did animals survive actual freezing in the ice.   In extreme changes of temperature, the proximal tentacles cease to react before the distal ones, and this is what might be expected from the relative sensitiveness of the latter.

Local thermal stimulation was attempted with a bent capillary heated tube, or cooled by a current of water such as Mast (:03) used in his experiments on Hydra.   The tube was held near the hydranth but not allowed to touch it.   A cold tube (ice water) caused no perceptible effect on any part of the hydranth, but a hot

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[1] The average temperature (readings at 8.00 A. M. and 5.00 P. M.) at Wood's Hole during the first ten days in August, 1905, was 19.8° C.

tube caused a restless indeterminate movement of the distal tentacles.

Photic Stimulation

No extensive experiments with light were attempted. Colonies were placed in the dark and then suddenly illuminated by a 16 c. p. electric light, or a shadow was cast over them after they had been illuminated for some time, but no observable reactions occurred in either case. It was also noted that the colonies grew just as abundantly on the sides of the piles most exposed to light as on those least exposed.

Summary

1.   The proximal tentacles of *Tubularia crocea* react to mechanical stimulation by bending toward the manubrium.

2.   The distal tentacles react to mechanical and chemical stimulation by bending toward or away from the mouth, and this action may be accompanied by a bending of the manubrium toward the stimulated side.

3.   Apparently no part of the hydranth is sensitive to very dilute solutions of meat juice, onion juice, and oil of cloves or bergamot (so called "odorous" substances).

4.   The minimum temperature at which reactions occur is 0° C. and the maximum about 26° C.

5.   Sudden change from strong light to shadow or from darkness to strong light has no apparent effect upon the animals.

BIBLIOGRAPHY

AGASSIZ, L.
  '62.   Contributions to the Natural History of the United States of
        America. Boston, 4°, vol. 4, viii+380+12 pp., pls. 20–35.
ALLMAN, G. J.
  '71–72.   A Monograph of the Gymnoblastic or Tubularian Hydroids
        London, 4°, xxiv + 450 pp., 23 pls.
MAST, S. O.
  : 03.   Reactions to Temperature Changes in Spirillum, Hydra, and
        Fresh-water Planarians. *Amer. Jour. Physiol.*, vol. 10, no. 4,
        pp. 165–190.
NUTTING, C. C.
  : 01.   The Hydroids of the Woods Hole Region. *Bull. U. S. Fish
        Comm.*, vol. 19, 1899, pp. 325–386, 105 figs.
PARKER, G. H.
  '96.   The Reactions of Metridium to Food and other Substances.
        Bull. Mus. Comp. Zoöl. Harvard College, vol. 29, no. 2, pp.
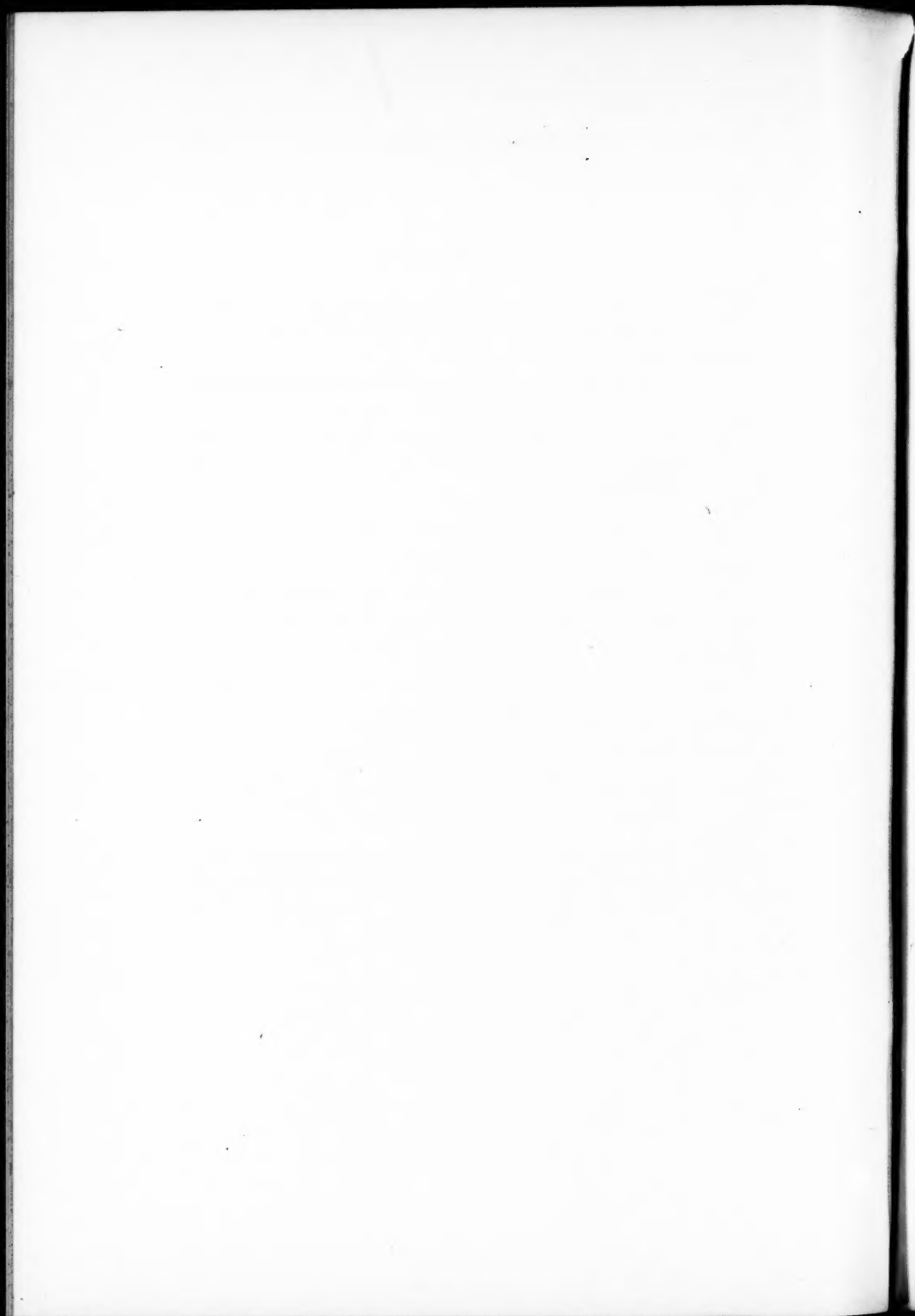   109–119.
TORREY, H. B.
  : 04.   Biological Studies on Corymorpha. I. C. palma and Environ-
        ment. *Jour. Exp. Zoöl.*, vol. 1, no. 3, pp. 395–422, 5 figs.
YERKES, R. M.
  : 02[a].   A Contribution to the Physiology of the Nervous System of
        the Medusa *Gonionemus murbachii*. Part I.— The Sensory
        Reactions of Gonionemus. *Amer. Jour. Physiol.*, vol. 6, pp.
        434–449.
YERKES, R. M.
  : 02[b].   A Contribution to the Physiology of the Nervous System of the
        Medusa *Gonionema murbachii*. Part II.— The Physiology of
        the Central Nervous System. *Amer. Jour. Physiol.*, vol. 7,
        no. 2, pp. 181–198.

PRESSURE AND FLOW OF SAP IN THE MAPLE[1]

K. M. WIEGAND

IT IS with some hesitation that a contribution is here attempted to the already voluminous literature regarding the ascent, flow, and pressure of sap in trees. Work on the maple has reached such a point, however, that it seems desirable to review critically our present knowledge to see which, if any, of our various theories are tenable, in how far, and why.

GENERAL ACCOUNT OF CONDITIONS ACCOMPANYING FLOW

In recent years the phenomenon of bleeding in plant tissue has come to be recognized as a very general one.[2] It has been found to occur in tissues widely different in nature, and under widely different conditions. Perhaps the bleeding of the root, accompanied by root-pressure, is the best known example of this phenomenon. The bleeding of trees in the spring attracted the attention of the early investigators, and has been the subject of considerable wonder and mystery ever since. Although it is a common phenomenon, we know comparatively little about the cause.

In late winter and early spring, if the maple is "tapped," that is, bored with an auger, sap will flow from the wound in considerable quantity, the flow being dependent very largely upon the temperature. Some other trees that bleed in the same way as the maple, though usually not to so great an extent, are *Juglans cinerea*, Cladrastis, Nyssa, and sometimes *Prunus serotina*. Later in the spring, just before vernation, the birch and grape bleed profusely, and, to a lesser extent, also Ostrya, Hicoria, Alnus, Malus, Cratægus, Salix, Ulmus, and perhaps a few other trees. Investigation of these various trees has shown that they fall

[1] Contributions from the Department of Botany of Cornell University, No. 109.
[2] Wieler, A. "Das Bluten der Pflanzen." *Cohn's Beiträge*, vol. 6, p. 1, 1892.

into two very definite groups as regards the bleeding phenomena, with a different source, and perhaps different cause, for the bleeding in the two cases.   Those which, like the maple, bleed early in the spring and are dependent upon temperature, constitute one class, while the late-bleeding ones, like birch and grape, which are not intimately dependent upon the temperature, constitute a class by themselves.   This paper is concerned entirely with the first of these two groups, and only a few words will be said about the other group at the close, as a matter of comparison.

Branches cut from certain trees at a low temperature and brought into the warm laboratory often show bleeding from the cut surface.   Clark tested sugar maple, white birch, elm, hickory, buttonwood, chestnut, and willow in this respect.   The maple soon began to bleed at the rate of 24 drops per minute, while the buttonwood bled 11 drops, and the hickory exuded a little very sweet sap, precisely as in spring.   The birch, chestnut, elm, and willow did not flow at all, and were not even moist on the cut surface.   I have often repeated this experiment with maple branches.   By passing the branch between the flues of a radiator a very vigorous exudation can frequently be obtained.   The trees that bleed in this way are usually those in which the vessels are comparatively saturated with sap.   According to Clark, a mercurial gauge attached to the end of a frozen branch of sugar maple indicated pressure and suction when the temperature was raised and lowered precisely as it would have done upon a maple tree during the ordinary alternations of day and night in the spring of the year when the sap is flowing.

Late Winter Flow in Maple and Other Trees

Considering its importance from an economic standpoint, the subject of maple-sap flow has received comparatively little attention.   In 1874 and 1875 Clark[1] published the results of several years of detailed work upon the maple.   These two papers really

[1] Clark, W. S.   *The Circulation of Sap in Plants* (*A lecture before the Mass. State Board of Agric. at Fitchburg Dec. 2, 1873*).   Boston, 1874.
    Clark, W. S.   "Observations on the Phenomena of Plant Life."   *22d Ann. Rep. Mass. State Board of Agric.*, Boston, 1875.

laid the foundation for our scientific knowledge of the bleeding in these trees. Not until 1903, after 28 years, did the next important contribution to the problem appear. This was the bulletin from the Vermont Experiment Station,[1] and here in one hundred and forty-one pages, are extensive records of experiments and observations of the most painstaking sort, representing the work of several men during a number of sugar seasons. It is the latest and most important contribution yet made to our knowledge of the subject. The last thirty pages of this bulletin are devoted exclusively to tables recording the results of typical experiments and determinations along the various lines of research.

In the succeeding pages I shall first attempt to present in condensed form the main facts connected with maple-sap flow as determined by these investigators and then turn to a consideration of the various theories in detail. In this review my own observations are added only when they are at variance with the others.

Both Clark and the Vermont workers found slight suction obtaining in the maple tree all through the growing season. This negative pressure, averaging 2.25 kg. per sq. in. fluctuated somewhat during the season, and to a slighter extent it also showed a daily periodicity. The latter, however, was not marked. Suction continued in most cases throughout midwinter until February or March. Under certain weather conditions, however, the suction frequently lessened until the zero point was reached and positive pressure resulted. During most of the time until March the tension of any sort was almost *nil*. Then the great oscillations which are characteristic of the sugar season, and which are closely related to the phenomena of sap flow, set in to continue until the buds began to swell. After the buds swelled, the pressure quickly disappeared. Sugar has been made from the maple, according to Clark, in all the winter and spring months from October to May, but, except in the spring, always in small quantities. The flow is said to be better in October and November than later, and rarely occurs in December, January, and early February except on very warm days. During the warm December of 1905 on several

[1] Jones, C. H., Edson, A. W., Morse, W. J. "The Maple Sap Flow." *Vermont Agric. Exp. Sta.*, bull. 103, Dec. 1903.

bright mornings following cold nights, sap flowed in considerable quantity from the stubs where branches had been pruned from maple shade trees on the Cornell campus. In the daily papers were reports of sugar having been made during that same month.

The best sap days are those in which a bright sunny morning with rising temperature follows a frosty night. The flow is greatest early in the morning, decreases gradually as the day advances, and ceases altogether during cold nights. It is not a daily periodicity, however, since on many days no sap flows, while again the flow may continue all night. It seems necessary that the rising temperature should cross the 0° C. line in order that there should be a good "run" of sap. If the temperature remains for several days above this point or for several days below it, the flow will rapidly diminish, and in from 24 to 36 hours cease altogether. The trees will then "dry up" and have to be retapped, even though the temperature fluctuates considerably. Hence comes the popular belief that the roots must freeze at night in order to obtain a good "run" the following day. Depending upon the weather, therefore, the sap flow is usually broken up into periods known as "runs." The swelling of the leaf-buds marks the end of the flow, or "season." If the day be too bright after the frosty night, the flow is apt to start briskly and soon lessen or cease, or if the wind be high the flow is soon checked. If the sky be overcast and the air has warmed slightly, a satisfactory run is likely to ensue. Alternate freezing and thawing,— moderately warm days preceded by freezing nights,— are the ideal meteorological conditions which promote the flow. Other things being equal, the flow is usually greater on southern exposures, since there the temperature extremes are greater.

A manometer attached to a bleeding maple tree shows that a considerable pressure exists within the tissues of the wood. It is this pressure which causes the outflow of sap, and which is the primary phenomenon to be considered. During the best sap days the pressure may rise as high as 6.5 to 10 kg. per sq. in., but is usually less. The pressure is highest on warm sunny mornings after a frosty night, and rises very rapidly after the first sunlight strikes the tree, so that on ordinary bright sap days it has reached its maximum at nine or ten o'clock. After that it gradually decreases

toward nightfall. The time of highest pressure does not there-
fore coincide with that of highest temperature, but often precedes
the latter by several hours. The maximum pressure on a good
day usually occurs about one and one half hours after commencing
in the early morning. If the following night is also cold, then all
through the night a moderate suction will obtain again, to be
followed by a similar abrupt rise the following morning. In one
case, Clark read on the manometer at 6 A. M. a suction sufficient
to raise a column of water 7.89 meters high, while as soon as the
sun shone upon the tree the mercury suddenly began to rise so
that at 8.15 A. M. the pressure outward was enough to sustain a
column of water 5.63 meters in height, a change represented by
more than 13.5 meters of water. On another morning the change
was still greater representing 14.45 meters of water. If the
night remains warm preceding a thaw, the fall of pressure will
be much less rapid, and a moderate pressure may continue all
through the night gradually vanishing during the following day.
After several days of thaw, suction may obtain most, if not all of
the time. If the temperature remains below freezing, suction
may exist for several days until the weather warms. There is
much to indicate that the normal condition in the maple at this
period is one of suction.

A rise of only a few degrees will often cause very great pressure
if the rise passes the zero point Centigrade. On the other hand
there may be considerable fluctuation in temperature without
great fluctuation in tension. This happens when the temperature
does not cross the zero line. The pressure fluctuations are greatest
early in the season. During the day, pressure forces into the
tap-hole all the sap located in the adjacent tissue. The suction
which ensues on freezing nights possibly draws more sap into
these tissues, and this in turn is forced out when the tree warms
up again. The entrance of air is hindered by the impermeability
of the membranes.

It was found in Vermont that trees so placed that the morning
sun shone on the top first, showed pressure there before in the
lower trunk. On a certain day when there were alternate periods
of bright sun and clouds, the gauges fluctuated very markedly.
Two pressure gauges were placed at a distance of twenty feet

(6 meters) from each other on an eighteen-meter tree, one being near the ground. As a general rule the lower gauge responded first, held its pressure longest, and fluctuated more. It showed more pressure during the day and more suction at night. The higher up the gauge, other things being equal, the less the pressure. Sap conditions began first in the twigs and external layers of the wood, gradually passed to the deeper tissues and lower parts, ceasing again in the same order. Clark, on the other hand, laid emphasis on the fact that the greatest suction as well as the greatest pressure was exhibited by the gauge at the top of the tree, but his tables show that this was very unusual. In general, his upper gauge registered much below the lower and fluctuated no more than did the latter. In one case Clark found that on the 19th of April the upper gauge showed little or no pressure while the lower one still indicated a pressure of about seven kilograms. In good seasons and good sap-spells the pressure directed downward in the trunk exceeds that directed upward. Later in the season the reverse may be true. Both pressure and suction are greater in the outer than in the inner tissues until late in the season. The outer tissues respond more quickly to temperature changes, and the pressure changes here precede those in the inner wood (hole 13 cm. deep in a tree 60 cm. in diameter) by about one hour. One depth might show pressure or suction while the other showed the reverse.

Pressure is not readily transmitted radially, in fact the transmission in this direction is very slight indeed. The lateral transmission of pressure is also very slight, not much more than three millimeters, but diagonally it is transmitted quite readily. Two years' trial in Vermont showed that a 4.5 kg. pressure under some conditions is transmitted through 244 cm. of distance. Smaller pressures are not transmitted so far. It seems probable that the pressure traverses the tissue entirely by means of the tracheæ. If two tap-holes are made, one in a vertical line above the other, and either one is opened, the fall of pressure in the other is abrupt at first but after a short time ceases, and is proportional to the distance between the holes. The remaining pressure represents the resistance of the inte ning tissue to the transmission of pressure. In one case a hole bored 122 cm. above a gauge in-

dicating 6.8 kg. pressure caused a drop of 3.2 kg. before a stop-cock could be inserted.

The sap flow varies in quantity with the pressure, so that a separate discussion of its characteristics is scarcely necessary. Some points, however, may be noted. On good sap days the quantity is often great, being as much sometimes as 12 liters in 10 hours. In some exceptional cases a flow of 20 liters per day has been recorded. Usually the flow is much less, 10 to 12 liters a day being an average flow for a moderately good sap day. According to the Vermont *Bulletin* it seems probable that a high registered pressure is not absolutely necessary to a good flow of sap, but that less pressure with longer duration will give equally good results. The rate of flow seems to depend also upon the amount of sap present in the wood around the tap-hole as well as upon the pressure behind it.

In general the flow is greatest near the ground. Clark inserted a spout at the usual height into a healthy maple which had never been tapped, and fifteen meters above this another spout was set into the trunk where it was 13 cm. in diameter. In addition, a limb 10.6 meters from the ground was also cut off where it was 2.5 cm. in diameter. In several hours the lower spout had bled 2.7 kg. of sap, the limb 56.7 gm., and the upper spout not a drop. Similar experiments with other trees gave like results. Both Clark and the Vermont workers found the down flow, as well as the down pressure, greater especially at the ordinary height of tapping. At both places, too, it was found that if an incision is made into a tree the sap will flow from the upper side of the cut and not from the lower unless late in the season. In late spring the flow is usually from both surfaces. In other words the flow is down from above in the maple, not up from the roots. Clark found that a severed tree would bleed profusely from the cut surface while the stump remained nearly dry. In Vermont it was found that in many cases severed twigs that started to bleed very early in the season frequently ceased before the flow from the tap-hole diminished very much. Lithium chloride inserted in the tap-hole showed that at times, at least, sap under pressure moves in the vicinity of the outlet hole at the rate of from 5 to 15 cm. per minute.

Clark found that pressure from the root during the sugar season was never more than very slight. Usually there was suction in the root throughout this period. At the Vermont Station the results were similar, the suction in one case being as much as 2.7 kg. There was a very slight fluctuation, however, between day and night as in nearly all roots. In no case was there a flow of sap from the root until late in April at the time when other trees bleed from the root. The root therefore as a source of bleeding in the maple is out of the question.

The sap of the maple is composed mainly of water with a few substances in solution. Of these, cane sugar is the most important, being present in from 1 to 5 % concentration. At first the sap is a water-clear, slightly sweet fluid, but as the season progresses the flow tends to lessen and the sap is apt to thicken and become cloudy or even somewhat slimy at times. Besides sugar there are usually small quantities of proteids, of mineral matter, more especially of lime and potash, and of acids mainly malic. Traces of reducing sugars are sometimes found, usually toward the last of the season. The sap from a tap-hole at ordinary height is considerably richer in sugar than the sap from the root, and also richer than that from taps higher up in the tree. The percent of sugar is also greater in sap from near the surface of a tree trunk than from deeper in the wood. There is some reason to believe that the actual distribution of stored material during the winter (starch and sugar) follows these conditions closely with less stored starch in the root than above ground, and less in the top than in the trunk, but accurate determinations have not been made. In Vermont it was found that at the beginning of the season sixty percent of the sugar came down from above. At the close of the season only about 39% came from the same source. There seemed to be a slight diurnal fluctuation in the percent of sugar, it being slightly greater toward nightfall.

The water content of the wood during the bleeding season varies from 30% to 55%. After the leaves come out it falls to from 19 to 30%. The Vermont workers found the relative amount for root, trunk, branch, and twig to be 29, 30, 34, and 37 respectively, but variations were so wide that the value of the series of averages is open to question.

The gas content of maple wood was found by the Vermont workers to be about 24% of the volume of the wood.   This gas consists largely of oxygen, carbon dioxide, and nitrogen, which are either produced by metabolism or have passed in from the air.

During the late winter of 1904 I made a number of observations concerning the disposition of the gas in the wood of a number of trees, and the results may here be added.   Sections were made with a razor either under water or under oil, and mounted in the medium in which cut.   Looking quickly through the microscope before changes could occur, the disposition of the bubbles of gas could be quite readily ascertained.   It was found that in the maples the vessels contained relatively little gas, sometimes appearing saturated with sap, while the wood fibers usually contained a large quantity of gas.   In some cases the latter were nearly filled with gas, in others only a part of them filled, and in a few specimens of sugar maple I could find no gas in any part of the section. Nyssa and Cladrastis showed little gas in the vessels during the bleeding season, and little in the fibers.   Juglans showed little in the very large vessels while the fibers seemed always to be filled with gas.   The other trees examined showed more gas than sap in the vessels.

The following table gives the results in detail:—

a. Sectioned under water, and under oil

Acer pseudoplatanus.   Considerable gas in vessels especially near cortex; gas in wood fibers.

Acer saccharum.   No gas in inner vessels, possibly a bubble in outer; gas in fibers.   Bled in room.

Acer saccharinum.   No gas could be found in vessels of this specimen; gas in fibers.   Branch bled in room.

Acer platanoïdes.   No gas found in vessels of this specimen; plenty in fibers.

Acer tartaricum.   Gas in vessels near bark, elsewhere none found; gas in fibers.   Branch became damp in room and bled a few drops if heated on radiator.

Acer insigne.   Rarely a bubble in vessels; gas in fibers.   Branch bled a little in room, more on radiator.

Acer campestre.   Considerable gas in vessels; gas in fibers.   Became damp only on radiator.

Juglans cinerea. Little gas in vessels, but fibers filled with gas. Branches bled on radiator.

Nyssa sylvatica. Wood quite highly saturated; little gas in either vessels or fibers. Bled on radiator.

Cladrastis lutea. Same as Nyssa. Bled on radiator.

b. Sectioned under oil

Salix fragilis. Large quantity of gas in vessels and fibers. Not even damp on radiator.

Catalpa speciosa. Same as Salix.

Populus dilatata. Vessels almost full of gas. Not damp on radiator.

Ulmus americana. Same as Salix.

Fraxinus americana. Full of gas; could blow through a piece several centimeters long. Not damp on radiator.

Vitis vulpina. Full of gas. Could blow through. Not damp on radiator.

Prunus virginiana. Large quantity of gas in vessels. Not damp on radiator.

Quercus alba. Much gas. Could blow through. Did not become moist.

Regarding tree temperatures, it was found that in holes 8 cm. deep they fluctuated less than air temperatures. According to the Vermont *Bulletin* slight variations in outside temperature caused little or no variation within the tree, which on many days did not show a range of 2° C. Considerable variation in external temperature, however, was followed in due time by corresponding, though less marked, internal fluctuation. Temperatures of –3° C. and –2.5° C. were the lowest recorded during the sugar season. Thermometers placed in 2.5 cm. deep holes on the north and south side of a tree showed during the winter a lower registration on the north side at all times except one day when the south wind was blowing.

The Gas-expansion Theory

About twenty-five percent of the volume of a maple tree is occupied by gas during the sugar season (*Vermont Bull.*). The presence of so much gas in the wood, together with its ease of detection and its known expansive qualities, early led the attention

of physiologists to this substance as a source of pressure, and until recently it has seemed to many a very probable explanation.

In 1767, Du Hamel[1] and Dalibard noticed that saturated wood became lighter when heated in hot water because of the loss of a portion of the contained fluid, and regained nearly its original weight when cooled, because of reabsorption. This was true except when the water in the wood froze, in which case the wood became again lighter in proportion to the frost.

Hartig,[2] in 1853, experimented with normal living wood using shoots of poplar, birch, etc. He found that, if these were taken before sap flow had normally begun and warmed over a lamp or in the hand, a small amount of sap would appear on the lower surface. If the temperature was near that at which sap flow normally appeared and the twig was normal, the excretion would occur to a slight extent simply by the application of the finger to the bark.

In 1860 appeared the exhaustive paper of Sachs[3] who was the first to put the gas-expansion theory on a firm scientific basis. A cylindrical stick of *Rhamnus frangula* 20 cm. long and 1.5 cm. thick, after having lain for 4 weeks in water of from 4° to 8° R. was treated and weighed as follows:—

6 hrs. in water at			20°	R. weighed	51.4	gms.	Water inside	28.6
16 "	"	"	"	3°	"	52.5	"	"	" 29.7
1 "	"	"	"	30°	"	51.4	"	"	" 28.6
2 "	"	"	"	25°	"	51.7	"	"	" 28.9
1 "	"	"	"	40°	"	51.2	"	"	" 28.4
1 "	"	"	"	2°	"	54.1	"	"	" 31.3
16 "	"	"	"	4°	"	54.2	"	"	" 31.4
1 "	"	"	"	30°	"	52.6	"	"	" 29.8
2 "	"	"	"	4°	"	54.3	"	"	" 31.5

Although, as seen from weights No. 2 and No. 7 which are at nearly the same temperature, there was a progressive increase in

[1] Du Hamel. *Du transport, de la conservation et de la force des bois.* Paris, 1767.

[2] Hartig, Th. "Ueber die endosmotischen Eigenschaften der Pflanzenhäute." *Bot. Zeit.*, vol. 11, p. 313, 1853.

[3] Sachs, J. "Quellungserscheinungen an Hölzern." *Bot. Zeit.*, vol. 18, p. 253, 1860.

weight independent of the experiment, still the abrupt change between Nos. 1 and 2, 2 and 3, 5 and 6, 8 and 9 shows very well the increase in weight when cooled and a corresponding decrease when warmed.

Similar results were obtained whether or not the wood was completely saturated, although all of Sach's experiments seem to have been with material rather near the point of saturation.

In the above experiment the weight of the twig dry was 22.8 gms. which subtracted each time gave the figures in the last column as the amount of water in the twig at each weighing. It will be seen that between 4° and 30° there was a loss of 1.6 gms. of water from the 31.4 gms., which would equal a loss of 5.09 gms. for each 100 gms. of water. Pure water, however, will expand only 1 gm. for every 100 gms. between the above temperatures.[1] Consequently water expansion alone will account for only about one fifth of the water excretion. Similar results were obtained for several other woods, including *Corylus avellana*, *Abies excelsa*, birch, beech, and oak, except that in the beech and some others the excretion was as much as seven times greater than the computed water expansion or even more. In many cases bubbles of air were extruded on warming, and none of the pieces of wood were saturated. Therefore Sachs concluded that the increased excretion of water must have been due to the expansion of gas, and this without doubt is the only true explanation of the phenomena with which he was dealing.

After recording this and several other similar experiments, Sachs felt warranted in saying that, if a rooted maple tree at a temperature of 0° R. in all its parts, is cut in two in the middle and the lower part with the roots is warmed, water will flow from the cut surface of the stump; and likewise, if the upper part with the branches is warmed, sap will flow from the other cut surface. If, on the other hand, the tree is not cut, then a pressure will arise in the trunk, which, if an incision is made, will result in a flow of sap out from both sides of the wound at the same time. Sachs considered that many phenomena were readily explicable by the assumption of water and air expansion in the wood.

[1] As given in Johnson's *Encyclopedia*, I find the expansion of water would be only 0.425 gms. for each 100 gms. between 4° and 30°; therefore less than the amount stated here by Sachs.

Sachs says: "If we assume that a stem and root has reached an even temperature between 0° and 4° R, and then suddenly a marked warming of the air occurs, at first only the crown and the stem are warmed, the thinnest twigs first of all; a part of their water is forced back into the thicker twigs, these in turn are warmed and a portion of their water is forced back into the cold trunk, which is warmed most slowly. Even this at length becomes warm and soon water is forced into the root. If now after the roots had become warm the trunk and top were to become cold through a sudden fall of temperature in the air, then a flow would occur from the roots toward the stem and from the stem toward the branches and so on." He was not sure whether this was the sole factor in the sap flow of the maple, birch, etc., in winter.[1]

But is the gas-expansion theory really capable of accounting for the *pressure* observed in the maple tree during the sugar season? In the Vermont report, a pressure of 24 lbs. (10.8 kg.) per sq. inch was given in one instance, while pressures of 10 to 15 lbs. (4.5 to 6.8 kg.) were frequent. The change in external temperature was in these cases about 5° to 8° C., which would mean a change of perhaps 3° to 4° within the tree; or, if the sun shone directly upon the tree, perhaps there would be a rise of from 5° to 10°, especially in the outer wood and twigs. Gas pressure increases at the rate of $\frac{1}{273}$ for each degree of rise in temperature. A 6.8 kg. pressure (atmospheric pressure per sq. inch) would therefore equal 6.8 $\frac{6.8}{273}$ kg. with a rise of one degree. A rise of from 5 to 10 degrees, as here supposed, would increase the pressure only from $\frac{34}{273}$ kg. to $\frac{68}{273}$ kg., a very small amount compared with the 4.5 to 9 kg. pressure actually obtained. The Vermont people are justified, therefore, in asserting that gas expansion cannot possibly account for the pressure observed in the sugar maple.

[1] For concise statement see his *Vorlesungen über Pflanzenphysiologie,* p. 245 (ed. 2). Sachs failed to distinguish between maple and birch in regard to the nature of flow. It may be also of interest to note that Sachs' conclusions were at once sustained by Hofmeister who also brought out additional evidence to their support (Hofmeister, W., "Ueber Spannung, Ausflussmenge, und Ausflussgeschwindigkeit von Säften lebender Pflanzer," *Flora,* vol. 45, p. 97, 1862).

Is the gas-expansion theory capable of accounting for the *flow* from the maple? A sap flow as high as 20 liters a day has been recorded in some instances, but under ordinary conditions the flow rarely exceeds 10 liters. If we take a tree 5 dm. in diameter and 20 meters high, and assume that the branches if pressed together in an erect position would approximately complete a cylinder with a diameter of the lower trunk and a height of the tree, we find that the volume of the tree would be approximately 3.927 cu. m. As given by the Vermont *Bulletin*, about 25% of this volume is gas or about 981,745 cc. This would expand for every degree 3596.1 cc. For a rise of from 5 to 10 degrees the expansion would be from 17,980.5 cc. to 35,961.0 cc. If we were justified in assuming the transmission of pressure without friction from all parts of the tree then this gas expansion would easily cover the ordinary 10,000 cc. flow, and even the maximum of 20,000 cc. But we are not justified in such an assumption. Resistance within the tree is great, and pressure, according to the Vermont studies, is not transmitted more than eight feet either way from the tap-hole. Therefore in such a section of the above trunk 16 ft. long (487.5 cm.) and hence containing 239,300 cc. of gas, a rise of one degree would cause an expansion of 876.5 cc. or 8765 cc. for 10 degrees. This would barely account for the ordinary flow of 10,000 cc. It is not true, however, that the whole of the water, even in such a section of the trunk, is in frictionless connection with the tap-hole. Water travels with great difficulty transversely from one annual ring to another, so that the outer layers only would probably furnish the main quantity of the sap. In such case the gas expansion of these layers would probably be only from $\frac{1}{5}$ to $\frac{1}{4}$ of the whole amount for the above section of trunk, and would scarcely account for even the smaller daily flows.

Moreover, the gas, as shown above, is at this season mostly, if not entirely, confined in the wood fibers. Gases diffuse through moistened cell walls only with difficulty so that a heavy pressure and considerable time would be required before the diffusion could be of much magnitude. In answer to this objection it might be claimed that if the wood fiber, instead of containing air alone, were partly filled with water, as is frequently true, then the expansion of the gas might press the liquid out with much greater

ease than it could pass out itself. However, the resistance in any case would be so great that to conceive of even a fourth of the total expansion being transmitted to the single small tap-hole is very difficult. Then, too, if the fibers are nearly filled with gas as seems true in many cases, early in the season at least, the expansion could be but slight before the limits of the cell cavity would be reached. As there would be no more sap to be forced from the cell and as the passage of the gas is difficult, the pressure at the tap-hole would necessarily cease altogether.

The gas-expansion theory cannot account for the pressures obtained, and can account for the volume of flow only by assuming very improbable conditions. It seems to be really out of the question. Sachs' interpretations were doubtless correct for the phenomena investigated, but the conditions in the maple tree are not of the same nature as those in the blocks of wood used in his experiments.

The Water-expansion Theory

One of the earliest as well as one of the most general of the beliefs regarding the cause of pressure in maple has referred it to the expansion of the sap itself as the temperature rose on a good sap morning. In presenting the facts favorable to such an interpretation it is important to note first that in maple during the flowing season the vessels are practically full of sap, while the gas is mostly localized in the wood fibers. It seems fair to suppose that the water can be forced from the vessels into the wood fibers only with some difficulty. Sachs showed that considerable pressure was required to force water through wood in a radial direction, and the Vermont experiments show that little pressure is transmitted laterally. Therefore if the temperature rises quickly in the morning the expanding water may be prevented from flowing at once into the fibers. Now if water is held under confinement free or nearly so from air bubbles, as is here the case, very slight expansion could cause a pressure of very great intensity for a short time. When later the water had penetrated the wood fibers, this pressure would rapidly fall just as it actually does fall in the maple tree. The maximum pressure in the maple occurs one hour or one

and one half hours after pressure begins in the morning. From this time on pressure falls gradually to the zero point. The highest pressure occurs, therefore, several hours before the time of maximum air temperature for the day, and the maximum temperature within the tree would be still later. Still the most abrupt rise is no doubt early in the morning when the sunlight first falls upon the tree, while the subsequent daily rise must be much more gradual. It might, therefore, be inferred that later in the day the percolation of sap into the fibers is sufficiently rapid to offset the expansion after the first abrupt rise.

When the temperature again falls below the freezing point, water would be drawn back into the vessels from the fibers and from more distant parts of the tree whither it had been forced. In many cases, as seen in the Vermont *Bulletin*, suction is greatest at first, but gradually decreases if the cold persists for some time. Suction during cold nights might be due either to the presence of a normal two or three pound suction in the tree at this season, or to the difficulty which the fluid that had passed into the wood fiber encountered in going back through the walls. When the temperature remains high, for a long time little pressure occurs though the fluctuations in temperature may be great. Only a previously low temperature insures a good run when the mercury again rises, and it is better if the cold endures for several days. A cause of this might be that at the high temperature, air creeps into the vessels from the expanded gas in the various tissues so that fluctuations are no longer transmitted. During the continued cold the air would pass back to the older cells thus leaving once more a solid column of water.

The objection that the sap occupies its least volume at 4 degrees and therefore at a temperature above that at which pressure begins, is invalid because only pure water behaves thus. With concentration of solution this density point falls much more rapidly than the freezing point, becomes less marked, and soon becomes identical with the freezing point so that with comparatively slight concentration it would either have disappeared entirely or at least have fallen to 0° C. when it could no longer be used as an objection.

It is possible, therefore, to explain the extreme pressure and many fluctuations peculiar to the maple by this theory, but it has

one very weak point.   This is the assumed high impermeability of
the fiber walls.   Although it is probably impossible to force water
through many such walls with the pressure observed, still we are
scarcely justified in assuming that one or two walls only separating
the vessels from the adjacent fibers would be so highly impermeable.
This seems improbable.

To determine whether this theory will account for the volume
of flow a few computations must be made.   In the Vermont
Bulletin the trunk of a certain tree was computed to contain 1220.5
lbs. (553,609.6 cc.) of water (p. 62).   The coëfficient of expansion
of water between 4° and 8° C. is 0.000,118 for the whole 4 degrees,
which would give an increase in volume of 65.3 cc. for the whole
amount.   A rise from 8° to 15° C. with a coëfficient of 0.000,729
would give an additional 403.5 cc.   Since tree temperatures vary
only a few degrees the expansion in any case would be only a very
small fraction of the whole flow.   For a tree 20 meters high and
5 dm. in diameter, the volume would be 3.927 cu. m., provided
that the branches if pressed together would approximately fill out
the trunk cylinder to the total height of the tree.   If a cubic foot
of dry maple wood weighs 43.08 lbs. the dry tree would weigh
2,709,895 gms., 45% of the tree is water, and 55% is wood; there-
fore, the weight of the water would be 2,217,332 gms.   The ex-
pansion from 4° to 8° C. would be 261.7 cc.   If it were possible
to believe that the water of the whole tree could flow to the tap-
hole without resistance, the flow would be still only one fourth
to one half of the actual daily flow.   Since, however, it has been
shown that pressure is transmitted only about eight feet each way
from the tap-hole, the volume of water which expansion might
cause to flow to the tap-hole would be only a fraction of the whole.
If water passes into the wood fibers to any extent the flow due
to expansion would be still less, only about $\frac{1}{12}$ to $\frac{1}{6}$ of the whole
flow.

The wood of the majority of trees is structurally so constituted
as to render the passage of water difficult radially from one annual
ring to another, while at the same time there may be fairly good
communication laterally owing to the bordered pits (in the Coni-
feræ) and the anastomosis of vessels in the broad-leaf trees.   It is
very probable, therefore, that not the whole 16-foot (4.8 meters)

section of the trunk would be tributary to the tap-hole, but only the few outer layers. If this be true, the flow to be expected from this source would be an extremely small fraction of the whole flow, not more than $\frac{1}{36}$ to $\frac{1}{18}$. It is obvious, therefore, that sap expansion cannot account for the flow in the maple.

Moreover, it is also not easy to see why air should pass back into the wood fibers on cooling below 0° C. at a time when there is actual suction in the vessels. Even if this were possible the theory cannot account for the flow, and can account for the pressure only by supposing the walls of the wood fibers impervious to water to an extent beyond the range of probability. The water-expansion theory must therefore be considered almost, if not quite, out of the question.

THE WOOD–EXPANSION THEORY

There is still another possible source of pressure due to heat expansion, namely, the expansion of the wood itself. Wood expands, as well as swells, more in transverse than in longitudinal direction. The coëfficient of expansion as determined by Villari[1] for dry maple wood is 0.000,006,38 in longitudinal direction, and 0.000,048,4 parallel with the radius. The coëfficient for wet wood is not recorded, but it must be considerably greater.

Let us suppose that the rising sun falls abruptly upon the tree or that the air temperature itself rises rapidly; then the outer layer of wood will be warmed much more rapidly than the inner, and probably the rise will be several degrees in the outermost layers. These outer layers will tend to expand, but being firmly united with the inner, such expansion is possible only to the extent of the elasticity of the wood. The result will be, therefore, a pressure among the elements composing the outer layers. The vessels of maple wood are quite large and surrounded by fibers. Since the latter contain the bulk of the wall-substance, they, in expanding, would tend to press upon the large cavities, the vessels. Since

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[1] Villari, L. "Experimental-Untersuchungen über einige Eigenschaften des mit seinen Fasern parallel oder transversal durchschnittenen Holzes." *Pogg. Ann. d. Physik u. Chemie*, vol. 133, p. 400, 1868.

the walls of the vessels are not so thick as those of the fibers, it is very likely that the large tubes would become to a slight extent collapsed. If they were completely filled with sap, the pressure would be transmitted directly to the pressure gauge. Later in the day, the temperature having penetrated to the inner layers of the tree, the pressure would disappear. Such a theory could also account for the very slight pressure observed in twigs which have a small diameter and are therefore quickly heated throughout.

Again, from another standpoint,[1] it is known that wood expands more across grain than longitudinally. Probably, like the swelling of wood cells, this is dependent upon the micellar structure of the walls themselves. As in the case of swelling therefore, it may be that the wood is free to expand tangentially, but is retarded radially by the massive pith-rays, the cells of which lie upon their side so to speak, and therefore expand less in the radial direction. The wood may in this way, independent of the contrast between inner and outer temperature develop an internal pressure, which would tend to compress the vessels as in the previous case. Pressure produced by this method, however, would not tend to disappear with the penetration of the heat.

As in the water-expansion theory, here, too, the same relation must be supposed to exist between the wood fibers and the vessels, and the same impenetrability of the walls must be assumed. Consequently the objection must again be brought forward to assuming such a high degree of impermeability. The expansion of wood is even less than that of water and hence a still higher impermeability must be assumed. Granted this impermeability, however, an almost unlimited pressure could be theoretically obtained.

Suction could be accounted for, as in the water-expansion theory, either by supposing a normal two or three pound suction in the tree, or by supposing that some fluid had passed into the wood fibers and was retarded in its return.

The occurrence of maximum pressure so early in the day could be accounted for under the first method of pressure-origin by assuming that after a short time the temperature in the outer and inner layers had equalized to a large extent; and under the other

[1] Roth, F. "Timber." *U. S. Dept. Agric., Dept. Forestry,* bull. 10, p. 32.

method by assuming that after the first abrupt expansion the sap flowed off through the tissues to the wood fibers, or to more distant parts of the tree faster than expansion took place.

Let us take the same case cited under the water-expansion theory of a maple tree 20 meters high and 5 dm. in diameter at the base, and a volume approximately 3.926,98 cu. m. as determined above. The radial coëfficient of expansion for dry maple wood is 0.000,048,4; if wet it would be greater, suppose 0.000,088,4. In tangential direction it would probably be greater still owing to the absence of pith-rays, say 0.000,15 or an average coëfficient of 0.000,119,2. The radius is 0.25 m., and for one degree of rise it would become 0.250,029,8 m.; the area would be 0.196,396 sq. m., and assuming that the length remains the same, the volume would be 3.927,92 cu. m., an increase of 940 cc. for one degree, or 3660 cc. for four degrees. This is only about 3.6 liters to be compared with the actual flow often of 10 or more liters. Under the most favorable conditions, presupposing the transmission of pressure from the most distant parts of the tree, and the equal penetration of heat, the flow would be only a fraction of the total flow on many days. If the pressure is transmitted only eight feet each way the flow would be slight indeed, and if produced only in the outer layers, as it would be necessary to suppose if we consider the pressure due to contrast between inner and outer temperatures, the flow would be insignificant.

In order that the pressure should become evident at all from such a source an almost absolute impermeability of the fiber walls must be assumed, otherwise the very insignificant amount of expanded water would in a very short time pass through and pressure would soon cease. This theory, therefore, fails to account for the volume of sap flow; and pressure can be accounted for only by assuming the almost absolute impermeability of the walls and saturation of the vessels, the former of which at least, is very improbable.

Combination of Gas- and Water-expansion Theories

It has been shown that the expansion of the gas cannot account for the pressure, and can account for the volume of flow only when the resistance within the tree is reduced to a point considerably

below what we should expect. Supposing, however, that it is able to account for the flow, is there any way of combining this with the water expansion so that the water expansion will account for the pressure and the gas expansion for the flow?

Early in the sap season the wood fibers appear filled with gas while the vessels are nearly or quite saturated with sap. The sunlight falling upon the tree in the early morning would rather abruptly warm the outer layers several degrees. Provided now that the walls of the fibers are slowly permeable to water, as has already been shown to be the case to some extent, then a high pressure would be produced by the expansion of the water in the vessels. Rapid expansion would quickly diminish, however, and the slow filtration of sap into the wood fibers would at first counter-balance the remaining expansion, then finally reduce the whole pressure gradually to nearly zero. Fall in temperature late in the day would aid this. Since some of the sap has passed into the wood fibers there would be suction at first at night. This would gradually decrease as the night progresses owing to the return filtration from the wood fibers. This theory could therefore account for the fall in pressure before the maximum temperature in the outside air is reached. Since the fall of temperature is always more gradual than the rise, due to the direct rays of the sun, the suction at night would never be as great as the day pressure, and it never is. After several days of rapid fluctuation of temper-ature, or after a period of warm weather, gas might separate in the vessels thereby rapidly diminishing the pressure to be ob-tained by equal fluctuations of temperature. This fact would account for the cessation of flow during a protracted thaw. A continued period of cold, however, might cause the absorption of gas and the resaturation of the vessels.

The flow can be accounted for by this theory only by supposing the wood fibers but partly filled with gas, thus allowing expansion. The expansion of the gas within the cells as the temperature rises will gradually force sap out into the vessels. The sap will then flow from the tree if tapped until the gas expansion is completed.

The objections to this theory are several. It must assume an impermeability of the wall substance which is beyond probability. Again, the volume of water produced by expansion is only about

one liter from the whole tree. Since this is distributed over the whole tree, and the numerous vessels expose an immense surface to the wood fibers, an almost complete impermeability would be necessary to affect the pressure markedly. But the gas expansion must later be supposed to overcome this same resistance. Considering the weak pressure of the gas and its compressibility it would be impossible for more than a small fraction of the whole volume of gas expansion to be transmitted to the tap-hole. The volume of flow is only barely accounted for by the total gas expansion, hence under these conditions only a small fraction of the flow would occur. Again, if gas expansion in the fibers causes flow, the latter would rise to a maximum slightly after the air temperature. The water expansion in the vessels would tend, however, to cause maximum flow at maximum pressure. The actual maximum would be a resultant of the two, so the curve of flow would reach its maximum later than the pressure curve and fall much more slowly. This is not the case with curves prepared from tables in the Vermont report. The curves of pressure and flow are almost exactly coincident.

It seems evident therefore that this theory also must be laid aside.

Combination of Wood-expansion and Gas Theories

It has been suggested that although the expansion of the wood is not sufficient to account for the total flow of sap, still, if combined with the gas expansion, the two together might account for both pressure and flow. Granting that the vessels are nearly if not quite saturated with water and that the gas is mainly within the wood fibers, both of which conditions seem to be true, then when the tree warms, the conditions would be as follows. The rapid warming of the outer layers of wood when the sun first falls upon them in the early morning would produce pressure as already outlined. With the vessels saturated, this pressure might be very great. As the day progresses the expansion of the wood goes on more slowly, and as the inner layers become warmed the outer layers are subjected to constantly decreasing strain. Meanwhile the sap would be constantly but slowly filtering through the walls

into the cavities of the wood fibers and thus compressing the gas there present. This filtration, although too slow to offset all the pressure early in the day would materially decrease it, and later overcome it altogether. But the gas has meanwhile become warmed and tends to force water back into the vessels. If the tap-hole is open, a flow due to the gas expansion would occur. Such a flow would be greatest early in the day when the wood expansion was also acting and gradually decrease but at a much slower rate than the decrease of pressure, due to the great elasticity of the gas and to the fact that the maximum volume of the gas would be at maximum temperature. The retarding effect of the slow conduction of heat would probably postpone the maximum still later. If we assume, therefore, that the expansion of gas at these temperatures is great enough to account for the volume of flow, then this theory might possibly furnish a means of accounting for the pressure and flow together.

The objections are several, and fatal to the theory. The most important objection lies in the probability that gas expansion cannot account for the flow, as outlined above under the discussion of that theory. Much less could the gas account for the flow if considerable force were required to transfer the sap through the walls of the vessels, as our present theory demands. Again, as described under the water-expansion theory, we have no good reason to assume such an almost absolute impermeability of the cell walls to water. Again, curves plotted from tables XVI and XVII of the Vermont report show that the sap-flow and pressure curves are practically parallel. The maximum pressure and maximum flow are coincident, and both decrease gradually and equally as the day advances. The maximum of each occurs usually within an hour or two after starting, and the fall begins some time before the maximum temperature of the air, much less of the tree, is reached.

This theory also must be laid aside as improbable.

The Freezing Theory

Professor Clark[1] and others were inclined to believe the pressure in the maple due to the expansion caused by the freezing of the water within the tissue. "The sap is separated from the cellulose of the wood by the cold and under ordinary conditions reabsorbed. The bleeding is, therefore, a sort of leakage from the wood, but this is doubtless increased by the elastic forces of the gases in the tree which are compressed by the liberated sap, and the expansive power must be intensified by the increase in temperature which always accompanies a flow.

"This theory explains the fluctuation of the gauges, and accounts for the singular fact that the upper one shows the most pressure and the greatest variations in as much as the branches and twigs would of course be most quickly and powerfully affected by the heat of the sun and the temperature of the atmosphere. The pressure of the expanded gases in a tree in a normal condition would facilitate the reabsorption by the wood of the liberated sap. Their contraction by cold would also cause the cessation of flow from a tree which was running, and produce the remarkable phenomenon of suction exhibited by the gauges at night or during frosty weather."

That the water would be drawn from the walls, our present knowledge of the freezing process shows to be true. First, the water in the lumen would congeal, then to these crystals water of imbibition in the walls would flow. If at the start the vessels are nearly or quite saturated, then the extra water from the walls, together with the expansion of the forming ice, would very naturally cause great pressure. In this wise the walls of the vessels or other chambers containing ice would be forced apart in proportion to their elasticity so that on thawing, the water would be under great pressure until sufficient time had elapsed for it to return again to the cells and walls from which it came.

It is difficult to compute the amount of flow that could be expected from such a source of pressure, but it might be considerable depending upon the amount of elastic expansion of the tracheal

[1] Clark. *Observations on the Phenomena of Plant-life*, p. 62.

walls, and the slowness of the return of water to its original location in the walls.

The objections to this theory are very serious. Firstly, the forces of imbibition are sufficiently strong ordinarily to insure a comparatively rapid return of water to the cell walls. The return of water to the walls in thawing winter buds I have observed to take place almost immediately. Flow and pressure throughout the entire day could not be accounted for in this way. Secondly, ice does not form in wood at the temperatures obtaining during the season of flow. A tree temperature of $-3°$ C. was the lowest obtained by the Vermont Station during this period, while on many good sap days the tree temperature at night was only $-0.5°$ or $-1°$ C. The overcooling point, not the true freezing point, is of importance in determining whether ice will be formed, and this is always several degrees lower than the freezing point in all plant tissue. Both are lower than the freezing point of pure water. Müller-Thurgau [1] found these temperatures for various sorts of wood as follows:—

	overcool. pt.	freez. pt.
Stem of small apple tree	$-7.2°$ C.	
One year shoot of pear	-3.9	$-0.22°$ C.
One year shoot of pear	-2.18	-0.25
Old wood of grape	-6.05	-2.85
Young wood of grape	-2.9	-2.1
" " " "	-3.5	-3.35
" " " "	-2.9	-2.5
Fir wood	-5.4	-0.4

The overcooling point seems to be greater in the more dense woods than in the grape probably because of the large vessels and watery sap offering little resistance to the inception of ice formation. Maple wood would be of the closer grained type. Ice formation would probably not commence before a temperature of $-4°$ to $-7°$ C. was reached. Dixon and Joly [2] found that ice began

[1] Müller-Thurgau. "Ueber das Gefrieren und Erfrieren der Pflanzen." *Landw. Jahrb.*, vol. 15, p. 492, 1886.

[2] Dixon and Joly. "The Path of the Transpiration Current." *Ann. Bot.*, vol. 9, p. 416, 1895.

to form in wood of Taxus at −10° or −11° C.   Therefore only during the coldest nights of the sugar season could ice ever form in the wood.   Some of the aberrations in the readings obtained by various investigators on very cold nights seem to be due to this cause, since it is not improbable that if ice actually does form in the vessels an increase of pressure at night rather than a decrease may be evident for a time.

Freezing, therefore, plays no important part in the phenomena under discussion.

Theory that Pressure is due to Activity of Living Cells

Having exhausted the possibilities in which mere physical force due to expansion is the main factor, we come now to the theories in which protoplasm plays the main part.

Pressure cannot be caused by the contraction of the protoplasm with forcible ejection of the sap because of the fragile nature of the ectoplasm.   Even if this were sufficiently strong no pressure could be obtained unless the exit from the contracting sack was into a reservoir unconnected with the space around the remaining surface of the sack.   Otherwise the extruded sap would simply occupy the space left by the contracting protoplasm, and no increase in volume would take place.   The alternative then, is for the pressure to be caused by osmotic phenomena.   Pressure and flow if accounted for in this way must presuppose an exudation, under pressure, of sap from the living cells.

Exudation is known to occur in Mucor as described by Pfeffer. In Spirogyra at very low temperatures near zero C., water has been observed to appear in droplets upon the surface of the cells.[1]

Drops of water are secreted from the cells of the pulvinus in Mimosa when stimulated, and from the sensitive staminal filament of the Cynareæ.   At present bleeding pressures in root and stem tissues can be accounted for in no other way.   The phenomenon

[1] Pfeffer. *Pflanzenphysiologie,* ed. 2.

Greeley, A. W. "On the Analogy between the Effects of Loss of Water and Lowering of Temperature." *Amer. Journ. Physiol.,* vol. 6, p. 122, 1901.

Livingston, B. E. *The Role of Diffusion and Osmotic Pressure in Plants.* Chicago, 1903.

is, therefore, one known to occur in plant tissues and is apparently much more widespread than was formerly supposed. Research is tending to show that bleeding occurs among cells of widely different tissues, and is probably to be considered a normal and very general phenomenon in plants.[1]

The exudation can be conceived to be produced in either of two ways: either by change in permeability of the diffusion membrane allowing water to pass with less friction, or by a change in osmotic tension. In regard to the first method it may be said that although diffusion membranes are considered to be freely permeable to water they really are not quite so. A force is required to press water through such a membrane as is shown by the fact that a bladder may be filled with water and suspended in air without the water escaping immediately. It is conceivable, therefore, that a portion of the cell membrane might become quite freely permeable to the solvent while the remainder continued dense. But so far as we know the resistance to the passage of water is very slight and plays no great part in the determination of pressure in osmotically active cells. So far as our knowledge goes, osmotic pressures are the same, no matter what membranes are used, providing that the solute is of the same nature and density, and that the membrane is permeable to it in the same degree, and also permeable to water. The osmotic pressure of water has been demonstrated in connection with some artificial membranes, but was always found to be slight. So far as we know at present all pressures of any moment in connection with semipermeable membranes are produced directly or indirectly by the action of the solute, and are proportional to the quantity of the latter present.

We have remaining the alternative of a change in osmotic tension. But such an alteration in osmotic tension is not sufficient in itself. Water might be excreted from the cells by a simple change in permeability of this sort, but the production of pressure in the surrounding tissue would be impossible, for as the water passed out from the cell, the latter would decrease a like amount in volume and no pressure would ensue, simply a change of location

[1] Wieler, A. "Das Bluten der Pflanzen." *Cohn's Beiträge*, vol. 6, p. 1, 1892. See also Pfeffer, *Pflanzenphysiologie*.

of the water with reference to the membrane of the cell. To obtain pressure externally by osmotic action it is necessary to assume a *flow* of water through the cell. But if the two reservoirs of supply and excretion are confluent then there will be a flow through the cell, in at one point and out at another and back again outside to the starting point, thus forming a circle of flow; and there would be no external pressure. The reservoir of supply to the cell must be distinct from the reservoir of excretion. Pressure will then be produced in the latter reservoir while at the same time, in the former a tendency toward suction will occur.

Flow through a cell will occur as Pfeffer [1] has already shown (a) if the solute passes through the membrane more easily at one end than at the other. Osmotic tension will here be less and the water will be forced out by the tendency to greater pressure at the other end. Flow will be in at the side of less permeability and out at that of greater permeability. Such a condition has been demonstrated experimentally in an artificial cell by Copeland. [2] Or (b) a flow will occur if the solute is more concentrated at one end of the cell. Water would enter in this case at the region of greatest concentration (greatest osmotic pressure), and pass out at the region of least concentration; and would continue to flow as long as the solute remained thus distributed. The difficulty in this case would lie in the maintenance of unequal concentration of the solute within the same cell. Since diffusion would soon equalize any such irregularity it could be accomplished only by the constant production of more solute at a certain point.

If pressure is due to the unequal permeability of the membrane to solute then there must always be a secretion of solute along with the sap into the chamber showing the increased pressure. Sap in this reservoir cannot be pure water, or even nearly pure water, unless the plant possesses some means of ridding the sap of such solute after its excretion either by its immediate change to solid form or its use in metabolism. In case pressure is due to an unequal distribution of solute within the cell then no excretion

[1] Pfeffer. *Pflanzenphysiologie*, ed. 2.
[2] Copeland, E. B. "Physiological Notes II, an Artificial Endodermis Cell." *Bot. Gaz.*, vol. 29, p. 437, 1900.

of the solute into the receiving reservoir would necessarily occur. The exuded sap, in such cases, might be pure water.

That the production of comparatively great pressure is possible in either of these ways is apparent. As shown by Pfeffer's table (p. 146) a difference of one percent in concentration of sugar solution is equal to a pressure of about 0.69 atmospheres or 10.3 lbs. (4.6 kg.). Twenty pounds pressure, which is about the maximum for the maple, would be equivalent to a difference of 2 % in concentration. This is not too great to expect considering that the percent of sugar in maple sap is from 1 to 5.5 and that local concentration might be much greater for a short time before diffusion. One might reasonably expect a higher pressure.

It is very difficult to bring forward any general theoretical evidence to establish the impossibility of either the excretion of solute theory, or the unequal distribution theory. But the fact that sugar actually passes into the vessels in large quantities lends a probability almost convincing to the idea that the increased permeability allowing the sugar to escape is also the cause of the pressure.

Maple wood is diffuse-porous, the vessels being scattered rather evenly throughout the annual ring, although they are perhaps slightly more numerous in the spring wood. The vessels are large, solitary, or, more usually, two or three together and surrounded by the moderately thick-walled wood fibers. These latter form the main bulk of the woody portion. Wood parenchyma is very scarce, and is confined to a few rows of cells in the vicinity of the vessels at points where they are adjacent to the pith rays. There is some question whether this tissue is wood parenchyma since there are no cross walls as ordinarily; or whether the cells are not wood fibers like the rest but with cellulose walls. I am inclined toward the latter view since the similarity is otherwise so striking. The wood fibers are without markings but the vessels are densely pitted. Pith rays are numerous in maple and very large (Fig. 1). An estimate seems to show that they occupy about one fourth of the volume of the wood. The larger ones are from 8 to 10 cells high and from 3 to 4 cells thick, ellipsoidal in tangential section, and extend from the cortex to varying depths into the wood, some reaching to the center. The cells of the pith

rays are slightly smaller in diameter than are the wood fibers, and the walls are thick and lignified. In radial direction they are from 3 to 5 times as long as wide. Through the various walls pits extend. These are sparse on the side walls adjacent to the wood fibers, and are simply very narrow canals extending at least part way through the wall. I was not able to demonstrate that

Fig. 1.— Maple wood, tangential section. Note the massive pith rays, and the large number of wood fibers.

they passed entirely through. At any rate the communication laterally through the walls must be slight, and passage difficult. Similar narrow pits, though somewhat larger, are very abundant on the end walls, and, except possibly for a closing membrane, are very obviously continuous from one cell to another (Fig. 2).

When the pith rays are contiguous to a vessel, large bordered pits are abundant in the common wall between them.   Elsewhere on the vessels, pits seem to be absent, except in the walls between the few wood parenchyma cells and the vessels.   Preparations stained with hæmatoxylin showed purple in the wood only where pith
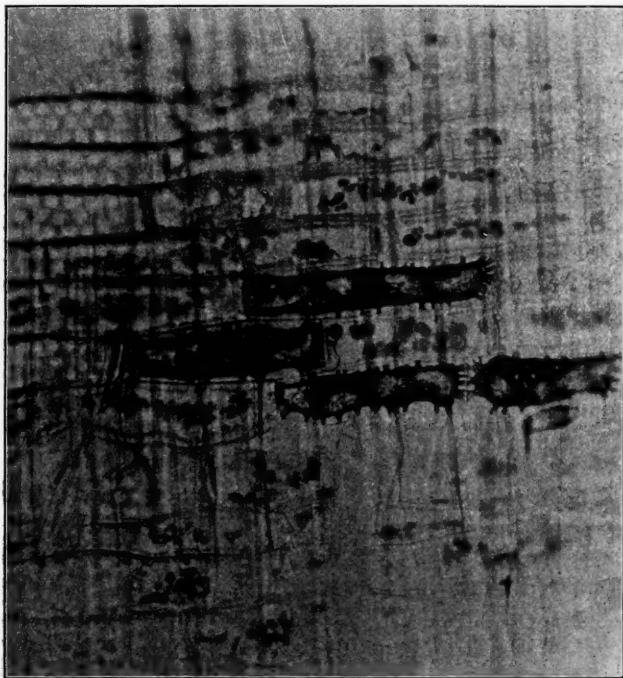

Fig. 2.— Pith ray of maple in radial view stained with iodine. The cavities of the four dark cells are filled with gas. This causes the pits to become very plainly visible. The dark bodies in the other cells are starch grains.

rays, or the sparse wood parenchyma touched the vessels.   It seems probable therefore, that all the walls are lignified except just at these regions that stain, and these probably remain cellulose.

On March 25th, sections stained with iodine after the hæmatoxylin showed the pith rays well filled with starch.   Starch was also present in abundance in the wood parenchyma cells about the

vessels, and in some of the wood fibers. The starch-containing fibers were mostly either adjacent to the vessels or clustered in a band at the end of each year's growth. The other wood fibers contained none at all. All of these cells with starch are living and contain protoplasm. In autumn we find the starch-containing cells of the maple packed full of this substance as in other trees. From the time cold weather commences until spring, starch is gradually converted into sugar. Fischer [1] has found this to be the case in many trees. The Vermont workers also found the starch content to decrease in early spring, and the sugar-content to increase. There is, however, no evidence to show that sugar is again reconverted into starch in late spring as Fischer states to be the case in some trees. It seems that the starch stored in the pith-ray cells and in the wood fibers described above is gradually converted into sugar as spring advances. Since there is no other source for the constantly increasing sugar content of the sap in the vessels it seems reasonably certain that this sugar escapes into the vessels from the starch cells where it is formed.

If pressure and flow are due to the living cells they must then be due to the pith-ray system, the wood-fiber system, or both, since these constitute the living part of the wood. In wood, as shown by Sachs, the only direction in which water passes with difficulty is radially. In longitudinal and tangential directions there is little obstruction to the flow. Moreover, although in the previous discussions in this paper, the fiber walls were hypothetically considered as almost impermeable to water, it seems more likely that one or even two walls intervening would retard the passage of water but little. At any rate, it is scarcely probable that a strand of starch-containing wood fibers contiguous to a vessel at one end would be more than two or three walls distant at the other end, and therefore there would be no way of obtaining for such a strand the two distinct water reservoirs necessary for the production of pressure.

In order that a homogeneous membrane should become suddenly more permeable at certain regions at a definite rising temperature

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[1] Fischer, A. "Beiträge zur Physiologie der Holzgewächse." *Pringsh. Jahrb.*, vol. 22, p. 73, 1891.

only, it seems reasonable that some stimulus must be applied, and since other factors are practically constant, it seems reasonable to expect this stimulus to be the rising temperature. It is difficult to think of any other factor among the conditions obtaining in a bleeding maple tree that could give such a stimulus. But the temperature changes would reach all parts of a narrow longitudinal wood fiber at almost the same time, and the stimulus would not in that case be unequal. For these reasons it seems improbable that the wood fibers can take any great part in the production of pressure and flow.

This is not the case, however, with the pith rays. Extending radially through the wood with few lateral pits and numerous end ones, they are admirably adapted for radial conduction without much lateral loss. Only at comparatively long intervals where they touch a vessel are they connected with the surrounding wood. The radial conduction of water in any wood is very limited, and the many layers of wood fibers in this case would form an especially efficient barrier between the inner and outer wood, each layer of which could here serve as one reservoir of the system. If we suppose the ray cells more permeable to sugar at the outer or the inner ends, then conditions are all suitable for the production of pressure and flow. The penetration of early morning heat would tend to warm all of the radially elongated ray cells at the outer end before the inner. Throughout the whole period of rising temperature therefore one end of each cell would be slightly warmer than the other. It is easy to conceive of this condition acting as a stimulus to cause a similar unequal permeability in all the cells.

We may conceive of the phenomenon occurring somewhat in this way. During the winter months but little starch is converted into sugar. As spring approaches, and up to the time of vernation, the stored starch is gradually converted. In this way the sap of the living cell must become highly concentrated and the osmotic force very great. During constant temperature, however, the protoplasmic membranes are either almost equally permeable to sugar over all parts of their surface, or not permeable at all. The latter is not probable since the concentration within the cell would soon become very great.

Rising temperature, however, by warming the peripheral ends

of the cells first, acts as a stimulus and causes the ray cells to be-
come more permeable to sugar at one end, which is the same end
in every case.   Since the greater pressure and sugar content is in
the outer wood, it seems probable that the outer ends of the ray
cells rather than the inner become more permeable, and the flow
would be therefore from the heart wood toward the cortex.   In an
untapped tree of course there would be scarcely any flow, simply
statical pressure, but sugar would pass into the vessels just the
same.   But the mechanism cannot be quite as simple as it seems
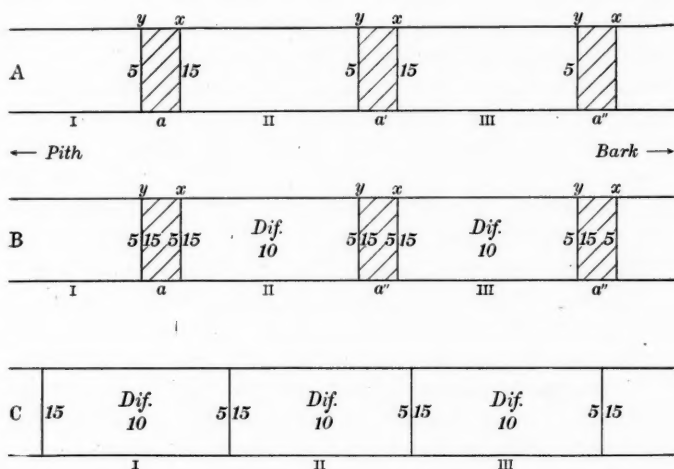

FIG. 3.— Diagrams representing chains of pith-ray cells.   I, II, III, cell cavities;
   a, cell wall separating membranes x and y.   Tendency to 15 gm. pressure
   at one end of the cell and 5 gm. at the other.

at first.   It will not do to assume simply that the membrane at
one end of the cell becomes more permeable to the solute in both
directions than does that at the other end.   Let A and B in Fig.
3 each represent three pith-ray cells, and the intervening shaded
portions the cell walls between.   Suppose that in A, at the x
membranes of each cell, there is a tendency [1] to 15 gm. osmotic
pressure, while at the y membranes there is a tendency to only

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[1] The word *tendency* is here used because in all parts of a liquid the hydro-
static pressure must really be the same.

5 gms. Sufficient sugar is passing out through the y membranes
to equal the difference of 10 gms. pressure. The sugar now in
chamber a would tend to exert a pressure of 15 gms. toward
membrane x and a pressure of 10 gms. against membrane y, which
would cause a reverse pressure of 10 gms. offsetting the pressure
caused by the cell. Only if the solute could be carried away as
soon as excreted could this mechanism work to produce pressure,
but the assumption of such freedom for the solute would neces-
sitate a still greater freedom for the solvent, which would make
the existence of two unconnected reservoirs impossible. It is
obvious therefore that no pressure can be produced by this method.
In order to obtain pressure it is necessary to assume unequal
permeability of the membrane in the two directions. In B we
may suppose each end membrane to show a tendency to 5 gm.
pressure on its left-hand side and 15 gms. pressure on its right.
Then water would pass from the cell to chamber a under 10 gms.
pressure, and from this chamber to the next cell under 10 gms.
again, and so on. This arrangement would also account for the
passage of sugar from one cell to another, which could not be
explained by the first method.

If, as there seems some reason to believe, the two membranes
on either side of the cell wall act as one owing to the numerous
plasma connections between them, then, as may be seen from C,
(Fig. 3), the assumption of unequal permeability of the same
membrane in opposite directions is the only one that will account
for the phenomenon.   It seems, therefore, that in any case we must
assume not simply that the membrane at one end of the cell is
more permeable than that at the other, but that each end membrane
is more permeable in the direction toward the bark than toward
the pith.

I see no reason why the pressure produced by the various cells
should not be accumulative, that is, if we have three cells each
producing a 10 gms. pressure we might expect a pressure of 30
gms. at the end of the series, or perhaps even double that if it is
assumed that the cell wall forms a distinct chamber.   For example,
in B (Fig. 3) sap from cell I is forced into chamber a under 10 gms.
pressure. Chamber a forces sap into cell II under a pressure of
10 gms. also; but, disregarding friction, cell I would have forced

water through the cavity *a* into cell II with 10 gms. pressure if *a* had contained only pure water. Is it not reasonable then that sap would be actually forced into cell II under 10 + 10 gms. pressure, and so on? If this is true then it would seem that the longer the pith ray the greater would be the peripheral pressure. Large trees would be expected to show more pressure than small ones. Unfortunately, records of pressure in trees of various sizes have not yet been made.

But it is not necessary or even probable that this is the case. The temperature each morning penetrates the wood in a wavelike manner. Only a few cells in each pith ray would be subject to the critical temperature at the same time; those farther within would be yet unstimulated, while those farther out would be recovering from the stimulation. Therefore but few cells would actually take part in the production of pressure at any one time. If this is true, the size of the tree would have little effect upon the pressure, within certain limits. I am inclined to suspect, however, that the diminished pressure in the branches and twigs may be, in the main, owing to this.

The question naturally arises why, if conditions are as here outlined, a pressure of 9 kg. in the outer wood would not necessarily be accompanied by a suction of 9 kg. in the inner wood, or indeed by 9 kg. plus the natural suction of the tree; but no such suction as this has been recorded. It may be mentioned that there seem to be no recorded accounts of search for pressure or suction at a greater depth than 10 to 13 cm. But the question may be considered from another standpoint. As stated above, the production of pressure would probably be confined to a comparatively few cells in each series. When pressure begins in the morning the active zone is near the bark, and water would be forced into a comparatively limited chamber, the contained gas would be rapidly compressed, and great pressure would be produced; but the water would be drawn from all the other layers of the trunk. The gas of all these layers would be expanded only a very slight amount, and little extra suction would be produced. Incidentally, the high pressures have all been recorded in the outer wood soon after flow began in the morning.

The rising temperature probably does not act as a constantly

increasing stimulus, but as an abrupt one.   As the critical temperature is reached the mechanism of stimulation is perhaps set off all at once, so to speak, and the maximum permeability is reached very soon, and consequently the maximum pressure and flow.   As the day progresses either the already converted sugar in the cell is exhausted or the membrane gradually recovers its normal condition as it recovers from the stimulus.   It seems more likely that the recovery is not due to the exhaustion of sugar content because on succeeding warm days without freezing nights there is still evident considerable fluctuation with temperature showing that some sugar is still there.   Then again, if the membrane remained unequally permeable, the small amount of sugar conversion that does constantly occur would tend to maintain a constant though slight pressure until by a fall to $0°$ C. the membrane became again equally permeable; but instead suction usually soon occurs.   It seems much more reasonable that after the abrupt stimulation the protoplasm should soon gradually recover its original condition.   The slight fluctuation in pressure that occurs each morning even during a thaw period is probably due either to a recurring but slighter degree of difference in permeability, or to an abrupt increase in sugar production induced by the rising temperature.   Since abrupt fluctuation in sugar production sufficient to cause pressure is improbable, the former hypothesis seems the more reasonable.

There is no reason to believe the conversion of sugar to be otherwise than normal, that is, gradual and constantly progressive, less rapid when the temperature is low and more rapid when higher according to the normal action of enzymes.   I see no reason to assume that at $0°$ C. enzyme activity is abruptly stimulated, thereby converting a large quantity of starch into sugar abruptly at one end of the cell, and thus causing pressure through the unequal distribution of the solute.   It seems to me more probable that at a low temperature the membrane is comparatively and almost uniformly impermeable over its entire surface.   Osmotic pressure is therefore high and the cells are very turgid.   A rise of temperature to the critical point now causes the abrupt stimulating shock, sugar passes out at the peripheral ends of the cells, and both pressure and flow become great toward the outer wood.   After

the first shock the cell begins to recover until the permeability is again equalized and pressure and flow cease. When the permeability is equalized at a high temperature, as well as at a low one, suction ensues. Hence the suction so often observed during the latter part of the thaw period. This suction may be partly due to the pressure having expelled part of the sap from the outer layers down toward the root or up toward the branches. Then after the restoration of equal permeability the tendency to equalize with the suction of the inner wood would tend to cause some suction in the outer trunk. The suction during cold nights may be partly due to the inner ends of the pith-ray cells being warmer than the outer thereby causing unequal permeability and consequent pressure in the reverse direction. But I believe that the wood of maple is normally under suction at this period, as is that of so many other trees, and that the return to suction either at a high or low temperature is merely a return to the normal. There is probably always some increase in permeability whenever one end of the cell is warmer than the other, hence pressure does not drop to zero until after the temperature has become equalized throughout the trunk each day; and on succeeding days, even if there has been no frost, the morning rise of temperature causes some pressure because of the same unequal warming. It seems reasonable to suppose that some sugar passes into the vessels at all times during the period of starch conversion, otherwise the concentration in the cells would become very great. The passage is probably less at low temperatures and greater at high temperatures. The warmer end of the cell is therefore always the one toward which flow is directed. Maple probably differs from other trees having starch stored in the pith rays mainly in (*a*) the sensitiveness to temperature causing marked unequal permeability at the two ends of the cell and (*b*) the spasmodic effect of this stimulus when the temperature is rising past a certain critical point.

The protoplasm of all sugar maple trees is probably not equally sensitive. For instance, for a number of years I have observed a tree which flowed comparatively little sap although this was unusually sweet, flowed less vigorously on a good sap morning than most trees, and continued flowing after the other trees had ceased during a warm spell. I suspect that here the protoplasm

was simply less responsive and less sensitive, less influenced by the rise in temperature, and much slower to recover after stimulation. In this way probably much of the observed individuality existing between different maple trees may be accounted for.

The quantity of sugar in the sap of any tree would be no indication of the difference in permeability, that is of pressure. This sugar content depends upon the total quantity of starch stored in the pith rays and the rapidity of conversion as well as on the permeability. The relatively greater quantity in the sap of the outer wood over that from the inner layers, on the other hand, would probably be proportional to the amount of pressure and flow.

The flow is not always as great as the pressure would lead one to expect. This may be because in these cases the available supply of water in the wood is less than usual.

Since each annual cylinder of wood with its system of vessels is in the form of a cone each extending higher on the tree than the preceding, water would probably tend to pass from the shorter layers to the higher ones, thus helping to raise the water in the tree. Water for the inner layers would probably be drawn primarily from the soil. Pressure in the twigs and branches is usually much less than in the lower trunk. This may be for three reasons, viz.,— because the temperature would equalize so quickly, because the radial chains of pith-ray cells would be shorter than in the trunk, or because of a less unequal permeability in the cells of the twigs. When a small branch or twig is cut off, sap flows from both surfaces but under no great pressure. I believe that the main portion of the flow in severed branches is due to the compressed air caused by the forcing up of sap into this part of the branch from the wood below.

Sugar probably passes from the wood fibers from the longitudinal faces if unequal temperature affects them in a similar manner, and owing to the narrow diameter of the fibers the flow thus caused would probably return again to the other side of the fibers without causing much, if any, pressure.

An objection to this theory which quickly comes to one's mind is the following. Why should the excreted sap pass through the pits into the next cell rather than around back between the plasma

membrane and the cell wall to the other end of the cell, thus producing a flow back through the cell without evident pressure? This seems impossible to answer at the present state of our knowledge, but it must be remembered that all theories of pressure produced by unequal permeability must meet this same objection. I believe, however, that a more critical study of the cell will eventually settle this point.

Regarding the water in the inner and outer layers, the Vermont *Bulletin* gives determinations up to a depth of 15 cm. only, and these are the only ones available. It was found on December 13th that the water content of the outer wood was considerably greater than the inner (37.5 % and 24 %). From that time until March 11th the percent in the outer layers decreased to 33.4 % while that of the inner wood increased to 39.1 %, thus giving a greater percentage for the inner layers. From then until April 28th there was an increase in both layers, but principally in the inner. At about this time the buds began to open and the water content of both fell abruptly. Along toward the first of June the content of the outer layers again became greater than the inner for a few weeks. These results seemed at first to present an objection to the present theory in that one would expect a greater water content in the outer layers into which the water would be forced from the deeper wood by the pumping action of the pith rays. After further thought, however, I am inclined to believe that the above readings are to be expected. The outer layers are subjected alternately to much greater pressures and suctions, while farther within the fluctuations are moderate, with predominating suction. It is reasonable to suppose that such violent fluctuations would gradually cause the accumulation of gas in these outer layers, and especially since these are near the exterior.

Why this particular temperature of from 1° to 3° C. should be so efficient in causing abrupt stimulation rather than any other is also an unsolved question. It must be noted, however, that several other phenomena seem to be connected more or less definitely with the same temperature, namely the exudation of water from the surface of Spirogyra threads already mentioned, and the gradual death of Coleus and other tender plants when subjected to this temperature but not frozen. This being the

temperature at which pure water is at its greatest density suggests that a re-arrangement of molecules in the water might be the source of the stimulus. The objection to this is that only pure water has this point of maximum density while in solutions of but slight concentration the point rapidly approaches the freezing point, and soon these two are identical.

It must be borne in mind that the idea that pressure is due to unequal permeability as above outlined is theory, not demonstrated fact. Its usefulness should lie in directing future investigation.

TREES THAT BLEED LATE IN SPRING

Trees of this second group show quite a different behavior in regard to the environmental factors, especially temperature. In general the seasonal flow steadily increases from its inception until the maximum is reached and then as gradually declines. The composition of the sap of the different species differs according to the date of flow, and especially the time of beginning. There is little similarity in the composition of the sap in the different species. That of birch contains a large percent (6 %) of sugar, but this is glucose, not cane sugar, while that of the grape is almost pure water and contains no sugar. If trees of this class are cut down, the stump surface will continue to bleed, in the birch and grape very freely, while the cut surface of the trunk will soon become dry.

According to Clark, the black birch begins to bleed about April 1, attains its maximum the last of April, and stops about the middle of May. The wild grape commences about May 1st, arrives at its maximum of flow and pressure about May 30th, and ceases early in June. The pressure and flow in both of these plants fluctuates very little as compared with the maple, and depends very little on the temperature of the air. Great changes in temperature affect the pressure slightly, but only after several hours. Nearly the whole fluctuation consists in a regular diurnal periodicity greatest at night and less in the morning. In this group of trees the phenomenon is without doubt one of root pressure, and the fluctuations are characteristic root pressure fluctuations.

According to Clark, holes bored at different heights in a birch tree showed that the column of sap was supported almost entirely by the pressure from the root at the base.

The difference between the bleeding phenomena of the group of trees which bleed in late spring, and then mainly from the root, and the trees of the maple type is, after all, perhaps mainly one of degree only. Although in early spring there is no bleeding from the root but rather suction in the maple, later in April when the leaves are about to appear, root activity is evident here also, though always moderate. Eliminating the peculiar earlier stem pressure the condition in the maple would be normal for the other group. In the case of young maple saplings the root activity begins considerably earlier than in large trees, probably due to the shallower root system. This also happens in the roots of young birch saplings. In the case of these young maple saplings I am inclined to believe that the flow was perhaps entirely due to root pressure.

On the other hand, the conversion of starch in the trunk and branch cells of the birch tree may take place at a later date than in the maple and without the accompanying spasmodic changes in the permeability of the membranes. Conversion seems to commence in the root in this case and progress upward, but this point has not been definitely proven. It seems more natural to expect the starch of the trunk in these trees as well as in the maple to be converted before that in the roots owing to the retarding effect of the slowly warming soil. Whether the trunk tissues of birch take part in producing pressure late in the season has not been carefully investigated. From the experiments of Clark it seems rather doubtful. As we have already learned, pressure is not a necessary accompaniment of the escape of sugar from living cells into the vessels.

If we accept the cell-activity theory for the sap flow in the maple as the most probable, then it seems likely that the difference between the trunk cells of birch and the other trees of this group and those of the maple lies in the inability of the temperature or any other stimulus to cause unequal permeability of the proper nature (*i. e.*, with the proper mechanism) to cause pressure. Therefore the only pressure evident in the birch is the so called root pressure.

Owing to the difference in structure between roots and stems the exact mechanism having to do with the root exudation phenomena in all these trees is a different problem, and not to be discussed here.

Molisch [1] has recently come to the conclusion that many cases of bleeding in trees through tap-holes or other wounds are local, and exist only after the incision is made. The wound here acts as a stimulus starting repair phenomena, with increased turgidity of the neighboring cells. He is inclined to believe, however, that the spring flows in maple, birch, and grape are general phenomena and of another category. To me it also seems that the conditions outlined at the beginning of this paper rather preclude the consideration of the maple phenomena as local. But I cannot see that the fact that they were local would in any way preclude the action of the pith rays as here outlined.

Summary

1. The source of pressure for the bleeding of trees in spring seems to be localized in different portions of the plant in different species.

2. Trees may be roughly classified into two groups in this regard: (*a*) those in which the source is mainly in the trunk and branches. These, as for example the maple, bleed early in the season. (*b*) Those in which the source is in the root only. These bleed later in the spring, as for example the birch and grape.

3. Only the problem of the cause of pressure in the maple is considered in this paper.

4. There seems to be an undoubted relation between the occurrence of pressure in the maple and the fluctuations in temperature.

5. In connection with no other fluctuating factor of the environment can such relation be shown.

6. Pressure exists only when the temperature is rising. When it falls or remains constant, suction occurs.

[1] Molisch, H. "Ueber localen Blutungsdruck und seine Ursachen." *Bot. Zeit.*, vol. 60, p. 45, 1902.

7. Except when the temperature is rising past the vicinity of 0° C. the pressure is very moderate or slight. In the latter case, however, it may rise to the height of from 6 to 9 kg. per sq. in. in less than one and one half hours. Pressure then begins to fall whether or not the temperature still continues to rise.

8. The flow is in a general way coincident with, and proportional to, the pressure.

9. Expansion of gas in the wood can by no means account for the amount of pressure exhibited by the maple; and such expansion is likewise probably incapable of accounting for the total amount of flow.

10. Water expansion in the wood, while it can readily account for the pressure, if confined, is probably not so closely confined, and at any rate is incapable of accounting for the volume of flow.

11. The expansion of the wood can account for the pressure only when the sap is confined, and such complete confinement is highly improbable. It cannot account for the volume of flow.

12. No combination of these theories can produce a sufficient explanation of both pressure and flow.

13. Freezing is not capable of accounting for the phenomenon.

14. The only theory so far advanced that can account for all the observed phenomena is the living-cell theory. This seems in most respects satisfactory.

15. Living cells could produce pressure by contraction only when the outlet of the cell is unconnected with the chamber immediately around the contracting membrane. The structure of the cell renders this improbable, and besides, the delicacy of the protoplasmic membrane precludes the formation of such high pressures by this means.

16. Osmotic phenomena seem the only resource. Only by flow through the cell from one reservoir to another, due to the unequal osmotic permeability at the two ends, does it seem possible to obtain pressure by this method. Osmosis in this way seems sufficient to account for even more than 9 kg. pressure.
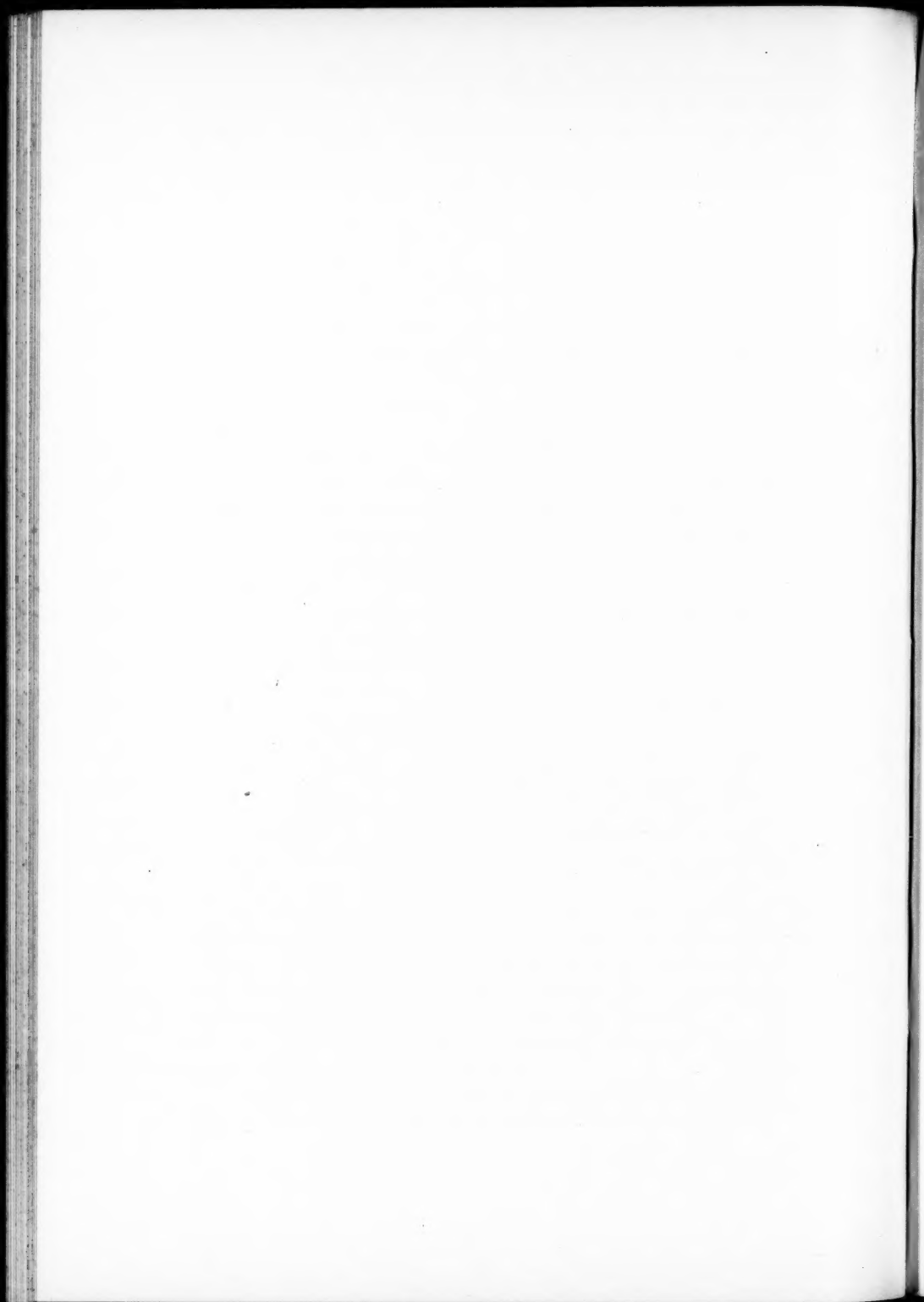
17. The pith-ray cells seem the only ones in the wood in position to fulfil the above requirements.

18. The most probable explanation at present is that the pith-ray cells, stimulated by the rising temperature, become unequally

permeable thus setting up a current and accompanying pressure from the pith toward the bark.

19.   The maple type seems to differ from the birch type principally in the localization of the active cells mainly in the trunk, rather than in the root; and in the spasmodic action of these under certain stimulation.

20.   It is quite possible that careful research will show no such irritability in the butternut and other trees of this group as is found in the maple.

NOTES AND LITERATURE

TEACHING

McMurry's Special Method in Elementary Science[1] is by far the most comprehensive treatment of the subject which has appeared in this country, and must prove extremely useful to the teacher in the public schools. The first half of the book treats of the aims and method of the teaching of elementary science,— the author at first makes a brave attempt to call it nature study, but throughout the greater part of the book calls it science,— the second half offers model lessons and a very full list of topics for a graded course of study.

Mr. McMurry insists that the topics shall come from the pupil's close environment,— Professor Hodge has already suggested that a louse on a pupil's head might be used for an instructive lesson on vermin,— and he has introduced as a new feature many topics dealing with the application of science to life. A study of the principles which govern the great inventions as well as our homely household appliances, can be made to appeal strongly to children. The author insists that a generation trained in the elementary problems of sanitation, physiology, and hygiene will not fall such an easy prey to the patent medicine frauds, and will back up boards of health in the fight for pure food and clean streets.

Professor Jackman some time ago outlined a course of nature study in which topics from every field of physics, chemistry, astronomy, meteorology, physiography, and biology were coördinated. Mr. McMurry extends the field still further, so that the variety of subjects to be handled would, we should think, appal any but the most unusually well trained teacher. It is a pity that the importance of the right method does not stand out more clearly. Many teachers will continue to convey information in many fields instead of training powers of reasoning in one. Mr. McMurry of course insists on the well known truths which should govern methods in science teaching, and often expresses his truths forcibly, but this book like all his

[1] McMurry, Charles A. *Special Method in Elementary Science for the Common School.* New York, The Macmillan Co., 1905. 12 mo, ix + 275 pp.

others suffers from an astonishing obscurity of style and unskilful presentation. The trail of the German "Pedagogik" is over it all.

In the chapter on method the place of imagination in science teaching is discussed; "children, primary teachers and poets" are encouraged to use a certain amount of license. It is amusing in view of recent controversies to see Mr. Burroughs figure as an example of the imaginative school of nature students.

There is a very full list of books which serve as an aid in science teaching.

R. H.

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EVOLUTION

Lotsy's Theories of Descent.[1]— This book is a series of twenty-one lectures delivered to students at the University of Leyden and designed "to awaken a desire for the investigation of questions relating to theories of descent." This aim it is well adapted to fulfil. The scope of the book is wide, and the discussions, while necessarily not exhaustive, never fail to be stimulating and to give the reader a view in perspective of a large part of the field of evolutionary thought and investigation. This is true in particular of the newer aspects of evolution, concerning which most of all a book of this sort was needed.

Lectures 1 and 2 are introductory in character. In them are discussed the limitations of evolution, the fact that it cannot explain everything, the beginning of the universe being quite beyond its sphere. The relation of science to religion is discussed and the absence of any real conflict between the two is shown; the ultimate questions of being and of consciousness are found to be beyond solution either by science or by religion. Lecture 3 deals with the origin of the earth, the newly discovered transmutation of one element into another, the origin of life and the fact that among organisms as among the elements one form may give rise to another. The dependence of organic form upon two sets of factors is noted, one set internal, the other external. Lecture 4 is devoted to the external factors or "morphogenic stimuli," such as light, heat, pressure, chemical composition

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[1] Lotsy, J. P. *Vorlesungen über Deszendenztheorien mit besonderer Berücksichtigung der botanischen Seite der Frage. Teil I.* Jena, Gustav Fischer, 1906. 8vo, xii + 384 pp., 2 pls., 124 text-figs.

of surrounding media, etc. Lecture 5 deals with adaptations and theories as to their origin, whether internal or external. Lectures 6 to 11 are on heredity. Spencer's comparison of heredity to regeneration of a broken crystal is shown to be incorrect by the fact of heteromorphosis among organisms. Nägeli's idioplasm theory and Weismann's germ plasm theory are shown to have been important as forerunners of the still more important ideas of de Vries, though all of these were anticipated in part by the work of Gregor Mendel. One of the lectures on heredity is devoted wholly to an exposition of Mendel's law (of alternative inheritance); another to variation curves, particularly to Galton's pioneer work in this field; another to filial regression, under which head are discussed the divergent views of Galton and Johannsen on regression, and the part played by the ancestors in the laws of heredity of Galton and Mendel respectively. In the final lecture on heredity the nature of the gametes (sex-cells) is shown to be the crucial question with theories of heredity, since in the gametes are contained all the internal factors of form. The phenomena of atavism, reversion, and latent inheritance (cryptomery, Tschermak) here come up for consideration.

Lecture 12 deals with the vexed question of the inheritance of acquired characters, which the author answers with a qualified affirmative; Lecture 13, with discontinuous variation as illustrated in the varieties of canary-birds, pigeons, and poultry, and among plants by numerous cases taken mostly from the works of de Vries and Korshinsky. Then follow two lectures devoted to the mutants of de Vries. In the next six lectures is given a historical survey of theories of evolution up to the time of Darwin, with a brief account of Darwin's life. In a subsequent volume the author proposes to discuss the Darwinian theory and the post-Darwinian literature.

The volume already issued is a marvel of prompt publication admirably done. The preface is dated September 11, 1905, and the plates contain half-tone illustrations made from photographs taken in September, 1905. Three months later the finished work is delivered in America, yet no evidence of haste is seen in the execution of the work; it is up to the usual standard of Fischer's publications, which statement in itself is sufficient praise.

W. E. C.

EXPLORATION

Scott's Voyage of the 'Discovery'.[1]— At the beginning of the seventeenth century, knowledge of the Antarctic regions was so meager that Quiros, a Portuguese favored by Pope Clement VIII, obtained permission from Phillip III, the King of Spain, to "prosecute a voyage to annex the South Polar continent and to convert its inhabitants to the true faith." Quiros never reached the Antarctic Circle but since that time, the occasional visits of navigators have added slightly to our scanty knowledge of this distant part of the earth, although real scientific work did not begin until the middle of the eighteenth century, when, in 1773, James Cook, with two vessels especially fitted for exploration, first crossed the Antarctic Circle. About 1820, Bellingshausen discovered the first known land (Peter Island) within the Antarctic Circle, and later in the century other expeditions touched at various points of the Antarctic continent and brought back more or less fragmentary and imperfect accounts of that region.

The last decade has seen great activity and interest in the investigation of this area, so that in 1901 no less than three expeditions, working in coöperation, were sent out to undertake a more exact study of the Antarctic seas and lands. The German expedition was led by Drygalski, the Swedish was in charge of Dr. O. Nordenskjöld, while the third, under the auspices of the Royal Geographical Society of London was commanded by Captain Robert F. Scott, R. N. The two volumes here reviewed, present a straightforward narrative of the work of the English party as modestly told by Captain Scott himself.

The preliminary chapters deal briefly with the previous explorations, the circumstances leading up to the organization of the expedition, the construction of the *Discovery* especially built for hard work in the ice, the equipment of the vessel, and the personnel of her officers and crew.

Sailing from England in July, 1901, the *Discovery* reached New Zealand in due course and on December 24, following, steered south for Victoria Land, the portion of the Antarctic continent assigned to this expedition for exploration. The remainder of the short polar

[1] Scott, Robert F. *The Voyage of the 'Discovery.'* New York and London, Charles Scribner's Sons, 1905. 8vo, 2 vols., illus. $10.00.

summer was spent in a preliminary reconnaissance of the coastline and the final selection of a favorable wintering spot in McMurdo Sound to the southeast of the volcanoes Erebus and Terror. Much of the coast thus visited was practically unknown and new land was discovered to the west of the Great Ice Barrier and was named King Edward VII Land. It was also determined that the Ice Barrier at this point had receded since the time of Ross's visit in 1841–2, and that the volcanoes Erebus (active) and Terror are upon an island.

In February, 1902, the *Discovery* anchored in the spot selected for winter quarters. Huts were erected on shore for the magnetic instruments and the routine of general scientific work was at once inaugurated. By the last of March, 1902, the vessel was frozen solidly into the ice, and throughout the Antarctic winter the scientific work was continued without interruption. By the first of November following, with the return of the sun, Captain Scott, Dr. E. A. Wilson, and Shackleton started on an extended sledge journey to the south. This party, traversing the surface of the Great Ice Barrier, followed south along the range of mountains that evidently represents the rugged coastline at this point, and after untold hardships returned at the end of three months having reached latitude 82° 16′ 33″ S., the most southern point ever attained by human beings. At this turning place, a lofty mountain was seen to the southwest and named Mt. Markham (15,100 ft.) while other great ranges stretched away to the south-southeast.

A second winter was spent in McMurdo Sound as the ice did not release the *Discovery* from its winter quarters. The little company was in good condition for the second season and the arrival of the relief ship *Morning* made it possible to recruit certain stores for another summer's work. This consisted chiefly in an expedition to the west to explore the Ferrar Glacier and the great tableland beyond which was found to rise for some 9000 feet. Over this inhospitable area Captain Scott and two other picked men made a remarkable journey on foot, and found it a "vast plain.... the most desolate region in the world," barren, deserted, windswept, and piercingly cold. The glacier and the Great Ice Barrier appear to be parts of the slowly receding outskirts of a polar ice cap that formerly was far more extensive.

By February of the following year, the ice floe broke up and the *Discovery*, in company with two relief ships, was enabled to return to New Zealand and thence home to England.

In his closing chapters, Captain Scott makes a few general remarks

on the nature of the land masses, the ice, and the ocean currents of these seas, and the two appendices by Ferrar and Wilson respectively, give a brief account of the geology and of the larger vertebrates. The observations on the penguins are of particular interest. The breeding grounds of the Emperor Penguin were for the first time discovered and valuable observations on the breeding habits were made at Cape Crozier where a small rookery was found. With respect to the so called 'pouch' of this and the King Penguin in which the egg is said to be carried, Dr. Wilson writes: "We are agreed that the term 'pouch' which has been used in this connection, is one which not only does not describe the matter, but is anatomically wrong and misleading. The single egg, or the chick, sits resting on the *dorsum* of the foot, wedged in between the legs and the lower abdomen; and over it falls a fold of heavily feathered skin, which is very loose, and can completely cover up and hide the egg or chick from view." This appearance is excellently shown in an accompanying photograph.

Although the scientific results have not yet been fully published, it seems certain that they will be the most valuable hitherto obtained by any Antarctic expedition.

The two handsome volumes of this work are well printed and abundantly illustrated with remarkably clear photographs as well as by numerous colored plates from sketches by Dr. Wilson. Two folding charts show in detail the coast of Victoria Land, the new land features discovered, and the routes taken in exploration. As a convenient method of keeping the reader informed of the lapse of time during the course of the narrative, the month and year corresponding to the time of the incident related, are printed at the upper inside margin of each page. The narrative itself is of intense and absorbing interest to the naturalist and the general reader alike, and is recommended to any who may be skeptical of the value of polar exploration. For in the author's own words: "The voyage of the '*Discovery*' was not conducted in a spirit of pure adventure, but we strove to add, and succeeded in adding, something to the sum of human knowledge."

G. M. A.

BOTANY

Anther Dehiscence.[1]— A study was begun in 1901 in connection
with an article on the pollination of Solanum and Cassia, published
in the *Kansas University Science Bulletin*, and continued in 1903 in a
thesis presented to the faculty of Washington University for the degree
of doctor of philosophy.   The author recognizes seven types of api-
cally dehiscent anthers and designates them as araceous, gramineous,
polygalaceous, ericaceous, dilleniaceous, Solanum-Cassia, and mela-
stomataceous.   First, these types are defined and the families and
genera representative of each are indicated.   Then there follows an
account of the floral ecology of the forms, except of the first four types.
Seven tables give the results of the arrangement of the data relating
to the geographical distribution of the genera of the several types,
and one shows the distribution of the flowering plants in general.
Fourteen geographical regions are recognized, based on the floristic
regions of Drude.   The Tropical American Region shows a maxi-
mum of Phanerogamia, the Indian Region being second.

The dilleniaceous, Solanum-Cassia, and melastomataceous types
have the corolla, or at least the limb, widely patent, and the anthers
basifixed and usually linear.

In the dilleniaceous type the stamens are indefinite, the anthers
usually elongate, the flowers usually actinomorphic and highly colored.
To this type are assigned 16 genera belonging to 6 families: five genera
of Dilleniaceæ, five of Elæocarpaceæ, three of Ochnaceæ, one each of
Theaceæ, Bixaceæ, and Flacourtiaceæ.   An Indian maximum is
indicated for this type, the Tropical American and Australian Regions
being next with the same number of genera; the Tropical American
Region, however, shows more species than the Australian.   As visi-
tors there have been observed: bees — Xylocopa, Euglossa, Bombus,
Apis, Melipona, Halictus, Centris, Podalirius;   birds — a brush-
tongued paroquet, Charmosyna, a honey-sucker, Myzomela;   flies
— Muscidæ.

The Solanum-Cassia type differs from the dilleniaceous in the
stamens being fewer and the filaments short.   In this category fall

[1]Harris, J. Arthur.   "The Dehiscence of Anthers by Apical Pores."   From
the *Sixteenth Annual Report of the Missouri Botanical Garden*, pp. 167–257,
issued May 31, 1905.

59 genera belonging to 19 families, 6 of which are Monocotyledons. The Monocotyledons are: one genus of Mayacaceæ, six of Rapateaceæ, two of Commelinaceæ, one of Pontederiaceæ, five of Liliaceæ, four of Amaryllidaceæ. The Dicotyledons are: one genus of Pittosporaceæ, nine of Leguminosæ, three of Tremandraceæ, four of Sterculiaceæ, eleven of Ochnaceæ, two of Dipterocarpaceæ, one of Flacourtiaceæ, sections of Begonia in Begoniaceæ, sections of Ardisia in Myrsinaceæ, one of Loganiaceæ, two each of Gentianaceæ, Solanaceæ, and Rubiaceæ. The table for the Solanum-Cassia type shows a maximum for the Tropical American Region, with the Australian Region second. Genera of visitors observed on flowers of this type are: bees — Osmia, Megachile, Ceratina, Xylocopa, Euglossa, Bombus, Apis, Trigona, Melipona, Halictus, Augochlora, Megacilissa, Melissodes, Podalirius, Centris, Oxæa; flies — Rhingia, Volucella; butterflies — Argynnis; birds — Mimus, Nectarinia, Chlorostilbon.

The melastomataceous type differs from the preceding mainly in the long filaments and in both locules of the anther usually opening through a single pore. Of the 161 genera of Melastomataceæ it includes all except 12, besides one genus of Leguminosæ and two of Bixaceæ. The Tropical American Region contains about 63 % of plants of the melastomataceous type, the Indian Region showing about 20 %. The observed visitors are: bees — Xylocopa, Bombus, Trigona, Halictus, Centris; flies — Syrphidæ; beetles — Cetonia, Buprestis; birds — Trochilidæ.

The table of genera of the three types shows a Tropical American maximum of about 57 %, and an Indian elevation of about 21 %. In Apidæ the Tropical American Region is first, with 64 genera of bees, the Mediterranean-Oriental Region second, with 51, the Northern Region third, with 50. Table J shows the distribution of Hymenoptera of all genera. K shows the relative abundance of genera of Apidæ. Diagram L gives curves for the distribution of endemic genera of the apically dehiscent types, of the Phanerogamia, of the Apidæ, and of all Hymenoptera. Diagram M shows the relative distribution of all genera of the same groups.

These curves indicate a direct relationship between the geographical distribution of the Apidæ and of the dilleniaceous, Solanum-Cassia, and melastomataceous floral types.

C. ROBERTSON

Freeman's Minnesota Plant Diseases.[1] — Simplicity, attractiveness, and full illustration are among the qualities of an ideal publication on agricultural science if it is to reach the people without the intervention of a middle-man. These qualities are possessed by a recent book on the diseases of plants prepared by Professor Freeman under the direction of the Geological and Natural History Survey of Minnesota,— a State which spends large sums annually on the study of its native resources and limitations, but the Agricultural Experiment Station of which is said never to have employed a special plant pathologist. The treatment falls under three general heads: fungi and their life history; economic applications; and diseases of plants. The book is likely to realize its author's hope of making the intelligent farmer who may read it an intelligent observer and assistant to the expert investigator.

<div align="right">W. T.</div>

Ward's Flowers of English Trees and Shrubs.[2]—This volume, the third in the author's work on trees, is devoted to a study of the flowers and inflorescences of the woody plants of England. It is essentially a book for the layman. It is to be recommended for its freedom from those grievous errors which so often characterize the "popular" books of a certain class of literary aspirants in this country. The amateur student will receive all the aid and instruction he needs, while the technical student will find a large amount of valuable material presented in à lucid and concise form.

The first part of the book is general and is devoted to a study of the more common types of flowers and inflorescences. The reader is first introduced, by means of a few well chosen examples, to the typical inflorescences and then to their variations. There next follows a treatment of the flower, its different parts, their nature and development. The general part of the book concludes with two chapters on the ecology of the flower. Naturally, these chapters concern themselves with the process of pollination and the characters of the flower which are correlated therewith. The entire material of Part I is admirably selected and lucidly set forth.

The second part of the book is special and takes the form of a man-

[1] Freeman, E. M. *Minnesota Plant Diseases.— Report of the Survey, Botanical Series,* v. St. Paul, published by the Regents of the University, July 31, 1905. 8vo, xviii + 432 pp., 211 figs.

[2] Ward, H. Marshall. *Trees, Vol. III. Flowers and Inflorescences.* Cambridge, University Press, 1905. 12mo., 402 pp., 142 figs.

ual for the classification of the common English trees, based upon their flowers and inflorescences. The willows are treated separately in an appendix. Tables are there given for the classification of willows when pistillate or staminate catkins are alone available.

The book is concluded with a copious glossary which defines the technical terms necessarily used in a book of this sort.

H. S. R.

Notes.— Dr. Scott's Wilde lecture on the "Early History of Seed-bearing Plants as Recorded in the Carboniferous Flora" is published, with illustrations, in vol. 49, part 3, of the *Memoirs and Proceedings of the Manchester Literary and Philosophical Society.*

The classification of Monocotyledons is further discussed by Delpino in series 5, vol. 10, of the *Memorie della R. Accademia delle Scienze* of Bologna.

A short illustrated note on the bark characters of trees, by Peet, is contained in *The Country Calendar* for November, 1905.

An address on plant morphology and taxonomy, by Kraemer, is published in the *American Journal of Pharmacy* for September, 1905.

A paper on contractile vacuoles and the frothy structure of protoplasm, by Degen, forms Heft 9–11, Abteilung 1, of the *Botanische Zeitung* for 1905.

Lindemuth (*Die Gartenwelt*, Oct. 28, 1905) has propagated Rex begonias from the leaves with long petioles. The petiole strikes root from the base and produces a crown of leaves at the tip. The petiole undergoes no great modification in form or structure except to increase somewhat in size but it may function as the stem of the plant for a long period of time.

The influence of color in floral ecology is analyzed in a paper by Delpino forming part of series 6, vol. 1, of the *Memoire della R. Accademia delle Scienze* of Bologna.

Studies on the composition and metabolism of apples, by Bigelow, Gore, and Howard, form *Bulletin 94* of the Bureau of Chemistry, U. S. Department of Agriculture.

The influence of environment upon the composition of the sugar beet is discussed by Wiley in *Bulletin 95* of the Bureau of Chemistry, U. S. Department of Agriculture.

The variability of wheat varieties in resistance to toxic salts is the subject of *Bulletin 79* of the Bureau of Plant Industry, U. S. Department of Agriculture.

A paper on the vitality of buried seeds, by Duvel, forms *Bulletin 83* of the Bureau of Plant Industry, U. S. Department of Agriculture.

A mechanical study of thistle-down as a parachute is published by Dandeno in *Science* of November 3, 1905.

Figures of some natural tree grafts are published by M. P. Wheeler in *The American Inventor* for November.

An analysis of the plant geography of Canada, by Drummond, appears in vol. 8, part 1, of the *Transactions of the Canadian Institute*.

Plants characterizing the life zones of Texas are listed by Bailey in *North American Fauna*, no. 25.

The forest conditions of the Gila River Forest Reserve, N. M., are discussed by Rixon in *Professional Paper 39* of the U. S. Geological Survey.

A note on G. J. Graham and his Mexican collections of 1827–9 is published by Britten in *The Journal of Botany* for November.

A popular account of Mexican vegetation, with instructive habit photograms, is published by Purpus in *Möller's Deutsche Gärtner-Zeitung* of October 7.

Five new Mexican flowering plants are described by Rose in no. 1427 of the *Proceedings of the U. S. National Museum ;* a new monotypic genus (Harperia) of Umbelliferæ and a new Zizia, from Georgia, are described by the same author in no. 1428 of the same publication, and Rose and House describe three Mexican violets (one new) in the succeeding no. 1429.

Part 7 of Captain J. Donnell Smith's *Enumeratio Plantarum Guatemalensium* has recently been distributed by the author.

The grasslands of the South Alaska coast are discussed by Piper in *Bulletin 82* of the Bureau of Plant Industry, U. S. Department of Agriculture.

The relations of the floras of the Northern Atlantic, the Polar Sea, and the Northern Pacific are considered by Simmons in Bd. 19, Heft 1, of the second Abteilung of *Beihefte zum botanischen Centralblatt*.

De Wildeman has begun the publication, through the Government of the État Indépendant du Congo, of an illustrated enumeration of the plants collected by Laurent during his Congo mission of 1903–04.

Important papers on Australasian botany are contained in current issues of *Proceedings of the Linnean Society of New South Wales* and the biological section of the *Reports of the Australasian Association for the Advancement of Science.*

Ridley has papers on Gesneraceæ of the Malay Peninsula, Aroids of Borneo, and New and Little-known Malayan Plants — II, in no. 44 of the *Journal of the Straits Branch of the Royal Asiatic Society*, issued in July last.

Cooke's *Flora of the Presidency of Bombay*, in vol. 2, part 2, issued in July last, reaches into the Verbenaceæ.

Schlotterbeck and Blome contribute a paper on the chemistry of *Bocconia cordata* to the *Pharmaceutical Review* for October, 1905.

A morphological and anatomical study of Claytonia, by Holm, forms vol. 10, no. 2, of the *Memoirs of the National Academy of Sciences.*

Britten publishes a note on Cliftonia in *The Journal of Botany* for October, 1905.

Interesting statistics of the cotton production and valuation of the world are furnished by Watkins in *Bulletin 34* of the Bureau of Statistics, U. S. Department of Agriculture.

An account of "Cratægus in Eastern Pennsylvania," distributed by Sargent on September 22 from the *Proceedings of the Academy of Natural Sciences of Philadelphia* for 1905, gives keys to the groups and species represented, of which latter 82, with 3 distinct varieties, are included,— 46 of the species being described as new.

A paper on Opuntia, by Berger, is contained in Engler's *Botanische Jahrbücher* of November 10, 1905.

Townsendia wilcoxiana is figured in vol. 5, fascicle 3, of *Icones Selectæ Horti Thenensis.*

Antennaria neodioica gaspensis is a new form from eastern Quebec, described by Fernald in *The Ottawa Naturalist* for November.

Power and Barrowcliff discuss the seed constituents of Hydnocarpus and Gynocardia in nos. 54 and 55, respectively, of the publications of the Wellcome Chemical Research Laboratories, of London.

An illustrated account of *Solanum commersonii* is contained in *Gartenflora* of September 1, 1905.

A chemical analysis of *Tecoma mollis*, by Kebler and Seidell, forms *Circular 24* of the Bureau of Chemistry, U. S. Department of Agriculture.

Illustrated articles on mangroves are contributed by J. A. Dimock and A. W. Dimock to *Country Life in America* for November, 1905.

Warburg gives an account of Phthirusa and Strutanthus — the mistletoes of rubber — in *Der Tropenpflanzer* for November, 1905.

Five additional species, and two varieties, are added to the hitherto monotypic genus Osmaronia by Greene in the concluding signature of *Pittonia*, vol. 5.

Habit figures of *Grammatophyllum speciosum*, a giant orchid, are given by Ridley in the May number of the *Agricultural Bulletin of the Straits and Federated Malay States*.

The somewhat aberrant nomenclature needs of orchid hybrids are discussed by Bohlmann in *Die Gartenwelt* of November 11, 1905.

The Xanthosomas cultivated under the name Yautia form the subject of *Bulletin 6* of the Porto Rico Agricultural Experiment Station, issued in English and Spanish.

No. 24 of Holm's "Studies in the Cyperaceæ," published in *The American Journal of Science* for September, 1905, deals with new or little known Carices from northwest America.

A well illustrated monograph of the wild and cultivated grasses of Iowa, by Pammel, Ball, and Lamson-Scribner, forming part 2 of "The Grasses of Iowa," has been issued as a *Supplementary Report of the Iowa Geological Survey*.

"Poa and its Commercial Fruit Characters" is the subject of *Bulletin 84* of the Bureau of Plant Industry, U. S. Department of Agriculture by Brown and Hillman.

Cavendish reports, in *The Indian Forester* for August, that after an interval of some 30 years *Dendrocalamus hamiltonii* has flowered throughout the Assam district in the wholesale fashion characteristic of the bamboos.

The storage and germination of Zizania seed is the subject of *Bulletin 90, part 1*, of the Bureau of Plant Industry, U. S. Department of Agriculture.

A Spanish hybrid of *Juniperus phœnicea* and *J. communis* is described by Cadeval y Diars in vol. 5, no. 12, of the current series of *Memorias de la Real Academia de Ciencias y Artes de Barcelona.*

The third and concluding volume of Braithwaite's *British Moss Flora* has recently appeared from Reeve's of London.

A new *Index Filicum*, by Christensen, is being issued in fascicles from the Hagerup press of Copenhagen. All of the pteridophyte names published from 1753 to 1905 are included, the treatment being much as in the *Index Kewensis* devoted to spermatophytes.

An extensive paper on the anatomy of *Acrostichum aureum* is published by Ethel A. Thomas in *The New Phytologist* of October 25, 1905.

A new fern (*Polystichum krugii*) from Porto Rico is described by Maxon in the *Proceedings of the Biological Society of Washington* for October 17, 1905.

Laing contributes a revised list of New Zealand seaweeds, and the first part of an account of the Ceramiaceæ of the island, to vol. 37 of the *Transactions and Proceedings of the New Zealand Institute,*— which contains numerous other botanical papers of interest.

A series of 64 unusually good three-color plates illustrates Dumée's *Nouvel Atlas de Poche des Champignons Comestibles et Vénéneux*, recently published by Klincksieck of Paris.

Publication no. 28 of the Bureau of Government Laboratories, Manila, consists of papers by Copeland on "The Polypodiaceæ of the Philippine Islands" and "New Species of Edible Philippine Fungi."

Under the title *Die Pilze von Tirol, Vorarlberg, und Lichtenstein*, Magnus has published, through the Wagner press of Innsbruck, a volume of 716 pages containing an account of over 3500 species, with bibliography, notes on synonymy, habitat, etc. The very full indexes alone occupy over 100 pages.

A voluminous catalogue of the fungi of the Low Countries, by the venerable Oudemans, constitutes vol. 12 of the second section of *Verhandelingen der Koninklijke Akademie van Wetenschappen* of Amsterdam.

An account of Norwegian Hymenomycetes, begun by Blytt and finished by Rostrup, has been separately issued from the *Videnskabs-Selskabets Skrifter* of Christiania, for 1904.

Guzmán enumerates 40 Salvadorean oil plants, cultivated or wild, in vol. 2, no. 14, of the *Anales del Museo Nacional* of El Salvador.

The destructive occurrence of *Trametes pini* in India is noted by Mayes in *The Indian Forester* for July, 1905.

Mushroom-growing and tissue-culture spawn production are described by Duggar in *Bulletin 85* of the Bureau of Plant Industry, U. S. Department of Agriculture.

A twin specimen of *Geaster fornicatus* is figured in the *Gardeners' Chronicle* of November 4, 1905.

The nuclear and sexual phenomena of Phyllactinia and other mildews are described by Harper in the recently issued *Publication no. 37 of the Carnegie Institution of Washington*.

A paper on the Monoblepharideæ, by Woronin, forms vol. 16, no. 4, of the *Mémoires de l'Académie Impériale des Sciences de St. Pétersbourg*.

A note on the Tuberaceæ of Portugal is published by Mattirolo in the *Atti della R. Accademia dei Lincei, Roma*, of October 15, 1905.

Uncinula conidiigena is the name of a new parasite of *Populus termula*, described and figured by Cocconi in series 5, vol. 10, of the *Memorie della R. Accademia delle Scienze* of Bologna.

Uromycladium is the name proposed by McAlpine for a genus of South Pacific leguminous rusts, related to Uromyces and Ravenelia, in *Annales Mycologici* for August, 1905.

The Japanese species of Uromyces on Sophora and Cladrastis are analyzed by Kusano in the (Tokyo) *Botanical Magazine* of August 20, 1905.

An account of endophytic adaptation shown by *Erysiphe graminis* under cultural conditions, is given by Salmon in vol. 198, series B, of the *Philosophical Transactions of the Royal Society of London*.

Diachœa cylindrica, a new Pennsylvanian species, is described by Bilgram in the current volume of *Proceedings of the Academy of Natural Sciences of Philadelphia*.

In a brochure recently issued from the Engelmann press of Leipzig, von Guttenberg considers the physiological anatomy of the galls produced by fungi.

Wheat improvement is considered by Lyon, in *Bulletin 78* of the Bureau of Plant Industry, U. S. Department of Agriculture.

The well known odor of moldy straw and hay is ascribed to a Streptothrix by Brocq-Rousseu in the *Revue Générale de Botanique* for October 15, 1905.

Hedgcock, in *Bulletin 90, part 2*, of the Bureau of Plant Industry, U. S. Department of Agriculture, differentiates the prevalent "crown gall" of apple trees into crown gall proper, and "hairy-root." The second is found not to be contagious, and the contagiousness of the first is not demonstrated.

A paper on the indigenous calabashes of Mexico, the Ayotli of Hernandez, is published in vol. 1, no. 2, of the *Anales de la Academia Mexicana*.

An illustrated article on Burbank and his work, by Honoria Tuomey, is contained in *Out West* for September, 1905.

Britten and Woodward have published some interesting correspondence concerning L'Heritier in recent numbers of *The Journal of Botany*.

Another of Fraser's Catalogues — this for 1796 — is reprinted in *The Journal of Botany* for November, 1905.

The recently issued 1904–05 *Report of the Government Botanist* for the Cape of Good Hope shows that the Cape herbarium now contains 44,189 sheets of specimens, of which 25,400 represent the Cape flora,— some 3000 of these being type sheets left by Harvey.

A new publication of the Tiflis Botanical Garden has been begun, under the title *Moniteur du Jardin Botanique de Tiflis*.

A series of illustrated articles on the London botanical gardens is being published by Perrédès in current numbers of the *American Journal of Pharmacy*.

A well illustrated account of the botanical garden at Buitenzorg is contributed by Ramaley to *The Popular Science Monthly* of November.

The Carnegie Laboratory at Tucson is described by Wittmack in *Gartenflora* of October 15, 1905.

An account of Dr. Kunze and his cactus collection, by Willey, is contained in *The American Inventor* for October, 1905.

Karasek gives an illustrated account of vegetation in the gardens of German Africa, in the *Wiener illustrierte Gartenzeitung* for November, 1905.

The Journals.— *The Botanical Gazette,* September: — Blakeslee, "Two Conidia-bearing Fungi"; Mottier, "The Development of the Heterotypic Chromosomes in Pollen Mother Cells"; Livingston, "Relation of Transpiration to Growth in Wheat"; Arthur, "Rusts on Compositæ from Mexico"; Shattuck, "A Morphological Study of *Ulmus americana*"; Billings, "Precursory Leaf-serrations of Ulmus"; Sheldon, "The Effect of Different Soils on the Development of the Carnation Rust."

The Botanical Gazette, October: — McCallum, "Regeneration in Plants — II"; Brown, "A Botanical Survey of the Huron River Valley — III"; Lyon, "The Spore Coats of Selaginella"; Schneider, "Contributions to the Biology of Rhizobia — V"; Eckerson, "The Physiological Constants of Plants Commonly used in American Botanical Laboratories — I"; Kraemer, "Further Observations on the Structure of the Starch Grain."

The Botanical Gazette, November: — Peirce and Randolph, "Studies of Irritability in Algæ"; Transeau, "The Bogs and Bog Flora of the Huron River Valley"; Ball, "Notes on North American Willows — I."

The Bryologist, November: — Haynes, "*Telaranea nematodes longifolia*"; Sargent, "Lichenology for Beginners — IV"; Chamberlain, "Some Common Errors"; Hill, "*Encalypta procera*"; Merrill, "Lichen Notes — I"; Holzinger, "A Note on Local Moss Distribution."

Bulletin of the Torrey Botanical Club, September: — Harper, "Phytogeographical Explorations in the Coastal Plain of Georgia in 1904"; Murrill, "The Polyporaceæ of North America — XII, A Synopsis of the White and Bright Colored Pileate Species"; Mackenzie, "Onosmodium."

Bulletin of the Torrey Botanical Club, October: — Cannon, "A New Method of Measuring the Transpiration of Plants in Place"; Harris, "The Fruit of Opuntia"; Abrams, "Studies on the Flora of Southern California"; Piper, "*Agropyron tenerum* and its Allies"; Cushman, "The Desmid Flora of Nantucket."

The Fern Bulletin, July: — Clute, "Species and Varieties among the Ferns"; Gilbert, "Observations on North American Pterido-

phytes"; Clute, "A Walking Shield Fern"; Gilbert, "Some Mexican Fernworts"; Terry, "More about the Ferns of Dorset"; Klugh, "*Nephrodium Boottii* or *N. spinulosum* × *cristatum*"; Eaton, "*Botrychium biternatum.*"

The Journal of Mycology, July: — Morgan, "A New Species of Kalmusia"; Morgan, "*Peziza pubida*"; Davis, "A New Species of Synchytrium"; Holway, "North American Salvia-Rusts"; Clevenger, "Notes on some North American Phyllachoras"; Lawrence, "Blackspot Canker and Blackspot Apple Rot"; Sumstine, "*Gomphidius rhodoxanthus* once more"; Sherman, "The Host Plants of *Panæolus epimyces*"; Kellerman, "Notes from Mycological Literature — XVI," and "Index to North American Mycology."

Journal of the New York Botanical Garden, September: — Britton, "A Lost Species of Begonia [*B. rotundifolia*] apparently Rediscovered"; Hollick, "Palæobotanical Notes"; MacDougal," Suwarro or Saguaro."

Mühlenbergia, vol. 1, no. 7: — Heller, "The Western Veratrums," and "A New Linanthus."

Mühlenbergia, vol. 2, no. 1, is occupied by an account of botanical exploration in California during 1905, by the editor, Mr. Heller.

The Ohio Naturalist, November: — Surface, "Contribution to the Life History of *Sanguinaria canadensis*"; Schaffner, "The Classification of Plants — II"; Fischer, "An Abnormal Cone of *Pinus laricio*"; Gleason, "Notes from the Ohio State Herbarium — IV."

Appropriate space is devoted to botany in the *Ontario Natural Science Bulletin*,— the newly launched journal of the Wellington Field Naturalists' Club, of Guelph, Ontario.

The Plant World, August: — Bessey, "How much Plant Pathology ought a Teacher of Botany to know?"; Reed, "A Brief History of Ecological Work in Botany (Conclusion)"; Nehrling, "An Indian Magnolia [*Talauma hodgsoni*] in America."

The Plant World, September: — Atkinson, "Outlines for the Observation of some of the more Common Fungi"; Lloyd, "The Barley Cone—I. Some Points of Structure"; Kinney, "Outline of a Course in Plant Culture."

Rhodora, September: — Pease, "Notes on the Accentuation of Certain Generic Names"; Sargent, "Recently Recognized Species

of Cratægus in Eastern Canada and New England — VI"; Fernald, "*Symphoricarpos racemosus* and its Varieties in Eastern America"; Howe, "*Lotus tenuis* as a Waif in Rhode Island"; Collins, "Phycological Notes of the late Isaac Holden — I."

Rhodora, October: — Sanford, "*Eclipta alba* in Mass."; Sargent, "Recently Recognized Species of Cratægus in Eastern Canada and New England—VI (continued)"; Fernald, "An Anomalous Alpine Willow"; Lewis, "Sclerolepis in N. H."

The first volume of the *Proceedings of the American Breeders' Association*, containing an account of the St. Louis meeting of 1903 and the Champaign meeting of 1905, has recently been issued, and contains a large number of unusually practical and some theoretical articles on both animal and plant breeding.

Torreya, September: — Greene, "Origin of *Rhus bipinnata*"; Harris, "New Fasciations"; Tidestrom, "Note on *Botrychium virginianum*"; Harper, "Some Large Specimens of Small Trees in Ga."; Clark, "Cotyledon- and Leaf-structure in Certain Ranunculaceæ"; House, "*Lespedeza velutina* Bicknell a Homonym."

Torreya, October: — Tidestrom, "Notes on the Gray Polypody"; Lloyd, "The Artificial Induction of Leaf Formation in the Ocotillo"; Berry, "An Old Swamp-Bottom"; Harper, "*Mesadenia lanceolata* and its Allies."

Zoe, August: — T. S. Brandegee, "A Collection of Mexican Plants"; "Palms of Baja California"; "A New Calamintha"; "Plants from Sinaloa, Mexico"; Greenman, "New Species of Mexican Plants"; Katharine Brandegee, "Notes on Cacteæ."